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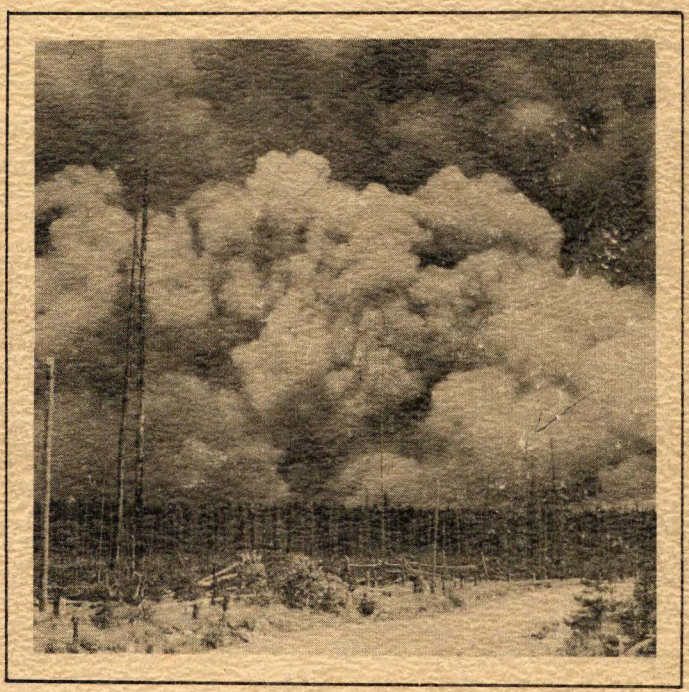
FIRE CONTROL PLANNING IN THE NORTHERN ROCKY MOUNTAIN REGION



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NORTHERN ROCKY MOUNTAIN
FOREST AND RANGE EXPERIMENT STATION
MISSOULA, MONTANA

PROGRESS REPORT
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FOREST FIRE CONTROL PLANNING

IN THE

NORTHERN ROCKY MOUNTAIN REGION

By

L. G. Hornby

The cooperative planning project described in this report was financed largely by the Division of Operation, Forest Service, Region One. Development of planning methods and supervision of plan work on national forests were in charge of the author, a staff member of the Northern Rocky Mountain Forest and Range Experiment Station.

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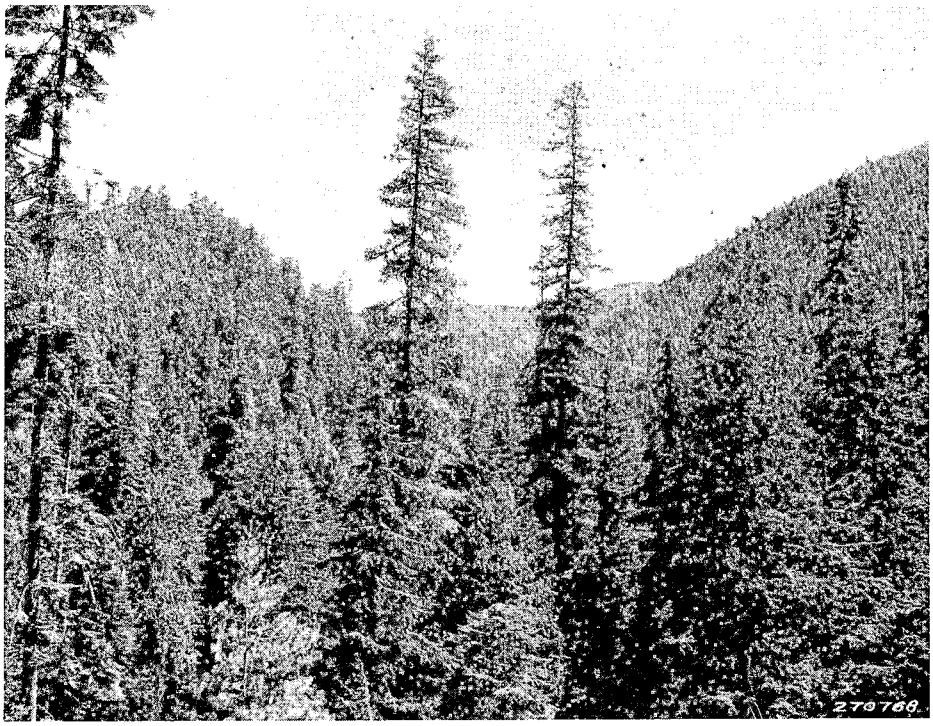

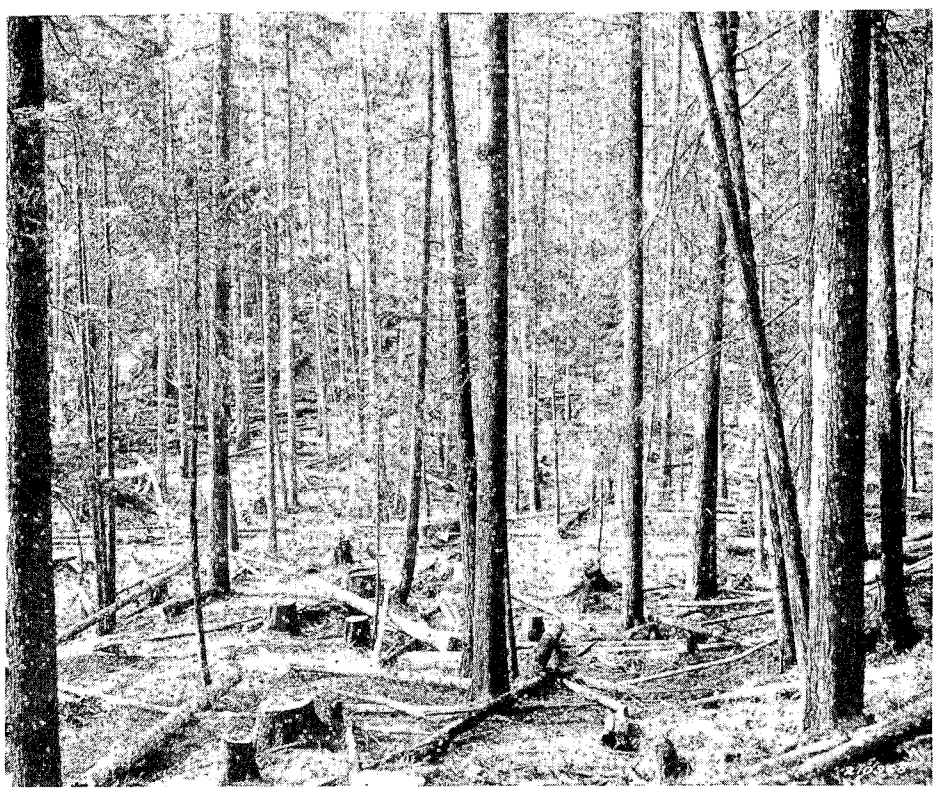

Typical conditions of forest and topography in unburned areas of the western white pine type.

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INTRODUCTION

In the northern Rocky Mountain region a high degree of protection from fire is necessary to perpetuate forest yields and communities industrially dependent upon them. On rugged and inaccessible areas a green, healthy forest cover is needed for recreation, erosion control, and regulation of water resources. Immense conflagrations continue to challenge the forester. In this and other forest regions of the United States fire conditions have been analyzed and the analyses have been made the bases of systematic planning to reduce burned acreage.

As systematic planning naturally followed the collection and examination of evidence, the literature on results of forest fires is older and more voluminous than that on satisfactory forest fire control measures. The earliest compilation of forest fire statistics for the whole United States was made by C. S. Sargent for the year 1880 and was published in the Tenth Census. Later census reports by decades were made by the Division of Forestry. Plummer *(15)* 1/, writing the third decade report in 1912, listed the well-known years and localities of great drought and heat in the United States beginning with 1662, and in Europe beginning with 1303. He gave the date, size, and location of twenty-one "historic" fires of the United States and Canada (1800-1910 inclusive), the ten largest of which ranged from 450,000 to 3,000,000 acres 2/. Writing also in 1912, Adams *(1)* gave considerable information on methods of fire prevention and suppression, much of which has not become obsolete.

In 1914 Dubois *(5)* published for the use of forest officers in California a comprehensive treatise on all phases of fire-control planning, giving Roy Headley particular credit for assistance. He assigned the duties of detection and initial attack to separate units of organization, discussed distribution of fire-control personnel in relation to localities of high danger, and advocated giving every forest area an integrated danger rating. He did not propose any method of combining the factors of frequency and occurrence, character of fuel, and damage. In the work described here an integration of these factors was made and applied to planning.

Publications of Show and Kotok *(16, 17, 18)*, issued in 1923-29, present findings as to the nature of the fire-control problem in California for different forest types and discuss the objectives of fire control.

1/ Italic numbers in parentheses refer to Literature Cited, p. 173.

2/ Whether these large fires developed from one or several small fires is not stated by Plummer.

These authors credit Roy Headley 3/ with originating the concept of the minimim-cost objective (least total cost of presuppression, suppression and damage, called "P+ S +D"), which he described in the California regional suppression manual of 1916. In 1924 they advocated *(17)* a minimum-damage objective, and in 1929 they stated *(18)* that the maximum damage allowable is burning of 0.2 percent of the region's area per year. In 1930 the Washington conference of regional foresters accepted *(22)* the theory of a maximum allowable percentage of burned area per year and set up such an objective for each forest type of the United States. In 1930 Show and Kotok announced *(19)* standards of detection and travel-time allowance for initial attackers (designated by them as "hour control") for each California forest cover type.

In 1930 Norcross and Grefe *(14)* worked out a method of determining the least cost of providing firemen and roads (or trails) that would satisfy travel-time requirements. This method was applied in a large amount of planning for the national forests of California, in which the locations of detectors were assumed to be unrelated to the locations of initial attackers and their road facilities. This method is inapplicable where the combined duties of detection and initial attack are assigned to the personnel of every station. For this reason it was not usable, except as a partial guide, in national forests of Oregon and Washington. In the northern Rocky Mountain region it was not used.

From the beginning of systematic planning in every region, it has been advocated that fire-control organizations be increased and decreased during the fire season according to number of fires to be fought and severity of burning conditions. In 1931, in developing methods of planning under the project described here, several degrees or steps of preparedness were specified to correspond with degrees of danger. It was evident that only through combining all factors of danger into a single rating for a particular day and locality could the corresponding degree of preparedness be put into effect in widely separated localities. In 1928 Gisborne *(8)* described methods of measuring separately some of the factors of danger. In the years 1932-1934 he developed *(9, 10)* a "fire danger meter" that integrated probable combinations of factors into seven classes of danger corresponding to the steps in preparedness being used in fire-control planning. As a guide to judgment the "danger meter" was increasingly relied upon, and in 1935 its use by forest officers in Region One was required. The term "danger" has been used inconsistently. The number of factors included has varied, and the important factor of probable damage, although it influences current practices, has not been recognized in a systematic way either in current or long-period plans.

3/ About 1917 this objective was developed independently by Elers Koch in the northern Rocky Mountain region, District One of the Forest Service.

In the northern Rocky Mountain region fire-control research and planning, expansion of fire-control organization, and speed and strength of attack on fires developed rapidly, with increasing appropriations, after the disastrous season of 1910. Each of the succeeding severe seasons 1914, 1919, 1926, 1929, 1931, and 1934 stimulated analysis, which in each case brought about restatement of requirements. In 1931 a study more comprehensive than any of its predecessors was instigated by Regional Forester Kelley and was undertaken by Gisborne and Hornby 4/ on the basis of a ten-year accumulation of detailed facts begun in 1920. The results of this study have guided the more complete planning of a desired fire-control system than was attempted previously.

Logically, fire-control plans are formulated for periods of five or ten years and for the current year. This report deals with periodic plans. More specifically it deals with the location and quantity of man power and the facilities required. Commonly recognized facilities for satisfying requirements as to speed and strength of attack include roads, trails, landing fields, means of communication, towers and other structures, as well as equipment and supplies. The Forest Service construction program of the region involving several million dollars worth of fire-control improvements was based to a large extent on the planning described here.

Although fire-control planning is not new, the methods described here are original in several respects. Requirements for detection were correlated with those for initial attack. A road system was designed to satisfy the combined needs of initial attack, light reinforcement, and heavy reinforcement with the least expense. So far as authority delegated to the planners permitted, the road requirements of general administration and utilization of forest products were correlated with fire-control needs. Other new features were the mapping of fuels according to probable rate of spread and resistance to control, and the use of classes of fuel rather than general cover types to determine requirements of speed and strength of attack. Man-power locations and road locations were selected through sorting combinations of individual coverage silhouettes over glass-top tables lighted from beneath. The integration of all danger factors into ratings of areas was used for the first time. One of the most important and satisfactory developments was that five years of plan work, 1931-35, covering 15 million acres, was consumated by actual construction, to a large extent without change. Equally valuable is the training of men in systematic methods of procedure. The supervisor of every forest and more than 100 other men of the region participated actively in the plan work. These men will continue to substitute analyzed facts for personal opinions and to recognize necessary interrelations among all the factors of fire control, and will carry this analytic habit into other work.

Fire Control Objectives and Practices in the Northern Rocky Mountain Region, 1931. Unpublished.

This presentation of fire facts and planning procedures is regarded as a report on progress up to the dates shown. In several cases the data constitute the only records available of conditions existing in the earlier years. In order to determine trends data were compiled to as early a year as dependable records permitted. Such charted trends do not become obsolete, in fact, if entered currently as contemplated, they provide a continuously improving guide to action. Although data have been entered in a few of the tables and charts to 1934, inclusive, a more complete analysis to determine the continuation of trends since 1931 is needed.

It is necessary to recognize that through the large increases in fire-control effort put into effect during recent years additional measures and costs of preparedness have been spread over a very large area for the purpose of catching the occasional difficult fires that previously escaped from initial attacks. Thus, the opportunity for obtaining a reduction of burned area proportional to increased expenditures has continually become less and less, and small gains now are as indicative of efficiency and progress as large ones were in the earlier years of fire control. Under these conditions, current investigations and analyses for the purpose of determining the most efficient procedures rank in importance with the measures of preparedness and control put into effect.

In considering the contents of this report and the practicability of applying the methods described, it should be kept in mind that experience has been made the basis for drawing conclusions. After working with fire-control failures, and some successes, for 20 years, the author's approach is that of endeavoring to show specific methods that have a chance of being successful and are still economically justifiable.

PART I
GENERAL DISCUSSION OF PLAN WORK, FACTORS INVOLVED, AND RESULTS

PREPLANNING CONSIDERATIONS

DESCRIPTION OF REGION

The information presented here applies to the 23 million acres of forest land lying in Montana west of the Continental Divide, in Idaho north of the Salmon River, and in Washington east of the Pend Oreille River. The analyses of experience apply specifically to the 16 million acres of this region protected from forest fires since 1906 by the Forest Service of the United States Department of Agriculture. Figure 1, *A*, shows the geographical position of the protected areas. Throughout this publication, these protected areas are referred to as "western forests of Region One."

The national policy that for many years governed the disposal of public-domain lands resulted in private ownership of the most productive and most accessible timberlands of the region. This left only the more remote and rugged forest areas for national forests. With the reverse ownership trend now well under way, owing to tax delinquency and to gifts and sales of cut-over land, public responsibility for fire control is increasing in the localities where forest soils are of highest value.

In general, the region consists of forest-covered mountains rising higher and more ruggedly eastward to the Continental Divide from the Columbia plateau, the major part of which is in Oregon and Washington. Altitudes range from 700 feet on the Snake River, at Lewiston, Idaho, to 10,000 feet on peaks of the Bitterroot Range and Continental Divide. Figure 1, *B*, shows a profile of the region from southwest to northeast in the direction of prevailing winds.

The headwaters of the following large tributaries of the Columbia River lie entirely or partially within the region; Kootenai, Clark's Fork, Flathead, Spokane, Clearwater and Salmon. Table 1 shows rough approximations of the average discharge of each of the larger rivers and their drainage areas. These data were collected by Regional Forester Kelley in 1935 for use as a guide in determining the importance of national forest areas is regulating streamflow, erosion, and silting of navigable streams within the Columbia Basin. The table shows the approximate drainage area of each stream that lies within the indefinite limits of Region One territory, the portion that lies within the exterior boundaries of national forests, and the percentage this last area is of the Columbia River drainage area that lies above the Dalles. The large area, and influential (though small) percentage, that lies within national forests of other regions was not determined, but is included in the figures of column five.

Table 1.--*Average flow and drainage area of Columbia River* 1/ *and tributaries in relation to national forests of Region One.*

River	Average discharge in second feet	Drainage area in square miles: Total	In Canada	In U. S. outside Region One	In U. S. inside Region One territory	Inside boundaries of Region One forests: Square miles	Percent of Columbia drainage area
Kootenai	34,000	19,450	14,550		4,900	4,138	1.8
Pend Oreille						13,744	5.8
Clark's Fork	25,000	25,820	1,190		24,630		
Priest	1,600	1,047			1,047		
Flathead	12,000	9,140	640		8,500		
Bitterroot	2,850 2/	2,813			2,813		
Blackfoot	2,330 2/	2,311			2,311		
Spokane	8,000	6,600		1,000	5,600	2,644	1.1
Snake	57,460	109,000		97,894	11,106	8,325	3.5
Subtotal	143,240	176,181	16,380	98,894	60,907	28,851	12.2
Kettle	3,000	4,260	3,160	1,100			
Colville	255	1,036		1,036			
Methow	1,660	1,850		1,850			
Chelan	2,120	963		963			
Okanogan	3,000	8,200	6,000	2,200			
Entiat	529	420		420			
Wenatchee	3,400	1,327		1,327			
Yakima	4,500	5,970		5,970			
All others	unknown	36,793					
Subtotal	18,464	60,819	9,160	14,866			
Total	161,704	237,000 1/	25,540	113,760			
Percent		100.0	12.7	56.8	30.5		

1/ The data apply to the Columbia River drainage area above the Dalles.
2/ Data missing. Quantity estimated proportional to Clark's Fork relation of discharge to drainage area.

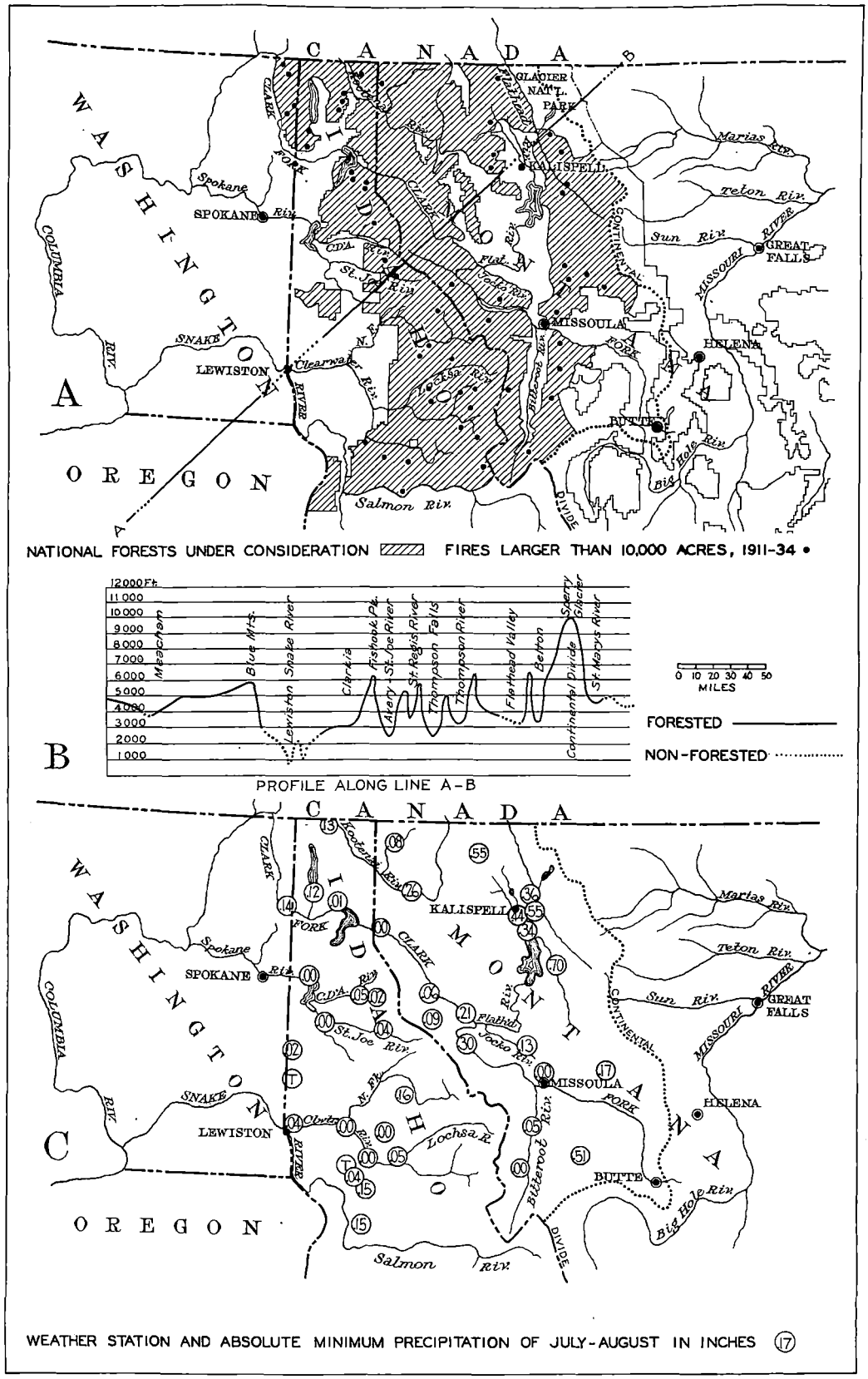

FIGURE 1

A - NATIONAL FORESTS AND LARGE FIRES

B - PROFILE OF REGION

C - WEATHER STATION AND MINIMUM PRECIPITATION OF JULY-AUGUST IN INCHES

When studying these data it is essential to keep in mind that much more precipitation falls within the forested portions of the Columbia Basin than in the much larger unforested portions. Also, forests defer the date of peak discharge through shading winter accumulations of snow and retaining in the ground large amounts of water that percolate slowly into stream channels. For these reasons, the 12.2 percent of area contained within the national forests of Region One exert influences immensely greater than indicated by area comparisons. The relative discharges from forested and unforested drainages are not known.

Although mining is a very important industry of the region and uses large amounts of timber in certain localities, very little acreage is occupied by its widely scattered activities, except in the vicinity of Wallace and Kellogg in Idaho, and Butte and Anaconda in Montana. Agriculture is highly developed only in scattered and relatively narrow intermountain valleys. The largest continuous strip of agricultural land, that including the Bitterroot, Missoula, and Flathead Valleys, has a length of approximately 150 miles and irregular widths up to 30 miles. As is shown by table 2, two-thirds of the regional area is better suited to forest and recreational uses than to general farming and grazing, the other land uses occupying considerable areas.

Climate and weather vary extremely. Average annual precipitation at weather stations, all of which are at the lower altitudes, ranges from 20 to 40 inches. Probably the average at the higher altitudes is in the neighborhood of 60 inches. July and August cover the critical part of the fire season. In this period precipitation is less than half of normal 30 to 60 percent of the time *(21)*. Within every block as large as a 20-mile square, the worst conditions of wind and drought that have occurred in any other such block must be expected. Figure 1, *C*, shows the minima of precipitation recorded for the July-August period at weather stations well distributed over the region. The highest minima, 0.55 inch and 0.70 inch (those for certain areas near Glacier National Park), are far below the quantity that can appreciably influence large runs of fires. Proof lies in the fact that fires burning 30,000 to 100,000 acres each have occurred around or near the stations where these minima were recorded. Figure 1 A, shows that fires larger than 10,000 acres have occurred in all parts of the region, in spite of organized fire-control efforts.

From October to April snow covers a large part of the land in the region that is higher than 5,000 feet. Average annual snowfall ranges from 60 to more than 200 inches unmelted *(21)*. Owing to the absence of habitations where the larger quantities of snow fall, the records available are too meager to be of much value in determining any relations that may exist between the snowfall of a given winter and the stream flow or burning conditions of the following fire season.

Table 2.--*Land use and population in region studied* 1/ 2/.

LAND USE	Million acres	Percentage of area
Forest and recreational	19.5	68
Other	9.0	32
Total	28.5	100

POPULATION		
Location	Population	
	Number	Percent
Within region		
Rural areas, and cities smaller than 3,000 3/	144,164	76
Cities larger than 3,000	44,562	24
Total	188,726	100
Cities larger than 9,000 3/ within 130 miles of region via road	217,568	
Grand total	406,294	
Cities 4/ larger than 9,000		
Within region		
Missoula	14,657	
Adjacent		
Spokane	115,514	
Lewiston	9,403	
Butte	39,532	
Anaconda	12,494	
Helena	11,803	
Great Falls	28,822	
Total	232,225	

1/ Boundaries of region are shown in fig. 1.

2/ Data from U. S. Forest Service land-use study made in 1934 and from U. S. Census of 1930. Data are for whole counties lying entirely or partly within the region.

3/ Existing cities fall naturally into certain size class groups. The ranges of such groups were used.

4/ Locations of cities listed are shown in fig. 1.

Severe lightning storms are normally to be expected between June 15 and September 15. If fuels have previously been dried to such a degree that they are inflammable, such storms frequently start large numbers of fires. (This subject is further discussed under the heading "Peak Loads.")

Tree species, forest types, age classes, and fuel conditions are highly intermixed, particularly where the older classes predominate. Fires are responsible for a great deal of this intermixture. The standard classification of timber types, and the plant species most important from a fire-control standpoint that are commonly found in each, are shown by table 3.

The region contains approximately 16,000 million board feet of merchantable western white pine, which constitutes 65 percent of the existing timber of this species and 18 percent of the white pine of all species in the United States. For lumber production this species has been, and probably will continue to be, the most valuable in the region. Ponderosa pine occupies a position of intermediate value between western white pine and the other timber species, the present stumpage values of which, even near main routes of transportation, are very low, or negative. In the form of poles western red cedar has about the same value per unit of volume as the lumber of western white pine, and the species, though constituting only a small part of any extensive stand, is more widely distributed through the region.

Although pure stands do not occupy large areas in the region, each of the trees listed in table 3 except western red cedar predominates over a considerable area in some part of it. Western red cedar invariably develops in the shelter of associated trees, which may be of any species occurring in the region. In considering fire control in the western white pine type, it is necessary to bear in mind that only 15 percent of white pine, by volume, is required to classify a stand as of this type. Frequently the majority of trees in a mature stand of the white pine type are of other species. In various mixtures, the species associated with white pine may be any of the trees listed except mountain hemlock and whitebark pine. Within a white pine area of only a few acres it is not unusual to find most of this species' common associates.

The frontispiece shows typical conditions of forest and topography in the western white pine type. Conditions on burned areas are discussed on page 15 and under Fuel Mapping, illustrations are shown in figure 16-A.

Table 3.--*Plant species important from the standpoint of fire control 1/ commonly found in timber types of western forests of Region One.*

Species 2/		Timber Type 3/										
Common name	Scientific name	Western white pine	Ponderosa pine	Lodgepole pine	Larch-Douglas fir	Douglas fir	White fir-cedar	Cedar-hemlock	Spruce	Subalpine	Brush	Grass
Trees												
Western white pine	Pinus monticola	x			x			x	x		x	
Ponderosa pine	Pinus ponderosa		x		x	x	x				x	x
Lodgepole pine	Pinus contorta	x	x	x	x	x	x		x	x	x	x
Whitebark pine	Pinus albicaulis								x	x		
Western larch	Larix occidentalis	x	x	x	x	x	x	x			x	
Douglas fir	Pseudotsuga taxifolia	x	x	x	x	x	x	x		x	x	x
Lowland white fir	Abies grandis	x			x	x	x	x	x			
Alpine fir	Abies lasiocarpa			x					x	x		
Engelmann spruce	Picea engelmanni	x		x	x		x	x	x	x	x	
Western hemlock	Tsuga heterophylla	x					x	x	x			
Mountain hemlock	Tsuga mertensiana						x			x		
Western red cedar	Thuja plicata	x					x	x	x			
Shrubs												
Ceanothus	Ceanothus velutinus	x	x	x	x	x	x				x	
	Ceanothus sanguineus	x	x		x	x	x				x	
Huckleberry	Vaccinium sp.	x	x	x	x	x	x	x	x	x	x	
Nine bark	Opulaster malvaceus	x	x		x	x	x				x	x
Ocean spray	Sericotheca discolor	x	x	x	x	x	x				x	
Service-berry	Amelanchier alnifolia		x		x	x	x				x	x
Rocky mountain maple	Acer glabrum	x	x	x	x	x	x	x	x	x	x	
Willow	Salix spp.	x	x	x	x	x	x	x	x	x	x	
Alder	Alnus spp.	x		x	x	x	x	x	x	x	x	
Menzezia	Menzezia ferruginia	x		x	x			x	x	x	x	
Yew	Taxus brevifolia	x			x		x	x	x			
Grasses												
Cheatgrass	Bromus spp.		x									x
Others		x	x	x	x	x	x		x	x	x	x
Tree Moss												
Staghorn lichen	Allectoria, or Usnea spp.	x	x	x	x	x	x	x	x	x		

1/ Condition of frosted vegetation not considered.

2/ Species confined to stream bottoms excluded.

3/ Occurrence of species is indicated by "x".

PERSONNEL PROBLEM IN FIRE CONTROL

Personnel management is a major consideration in planning fire control. No degree of effectiveness in other phases can offset handicaps existing in it.

The industries and population of the region have an important bearing on the fire problem, aside from being sources of fires. Fire control is concerned with location, quantity, and experience of man power available for the regular seasonal organization and for sudden calls to large fires. While the rural population is the best source, the seasonal peak of rural activity coincides with that of fire control. Table 2 shows the city and rural populations within the region and also the adjacent city populations, from which large numbers of laborers can be drawn on short notice.

Unsettled industrial conditions make it impossible to determine what proportion of the population is available as heavy reinforcements for fighting large fires. In the past, during the most severe fire seasons, the supply was easily exhausted in any and all localities. Transients collected from freight trains, hobo camps, and other sources have frequently been used, and have been imported in large numbers from as far as Seattle. The Civilian Conservation Corps has recently become an important factor.

For uniformly efficient initial attack, it is necessary that trained and experienced men be charged with the responsibilities of detection and smokechasing 5/ and be stationed previous to the occurrence of fire. Development of a dependable supply of such man power has been recognized as a vital need for many years. In spite of its importance the progress made has been erratic and not great.

The normal task of detection, and of going as quickly as possible to forest fires and handling efficiently the kind that cause most of the region's burned area, ranks in difficulty and importance with recognized skilled crafts.

No industries of the region require increased man power during winter months. The total of summer-season wages that can be accumulated in fire control and other short-time jobs does not constitute an annual income attractive to vigorous, ambitious men looking for permanent occupations and agreeable living conditions.

The many jobs to be done make it necessary for a fireman to occupy several different stations within a season, and frequently to live alone during the peak fire-load months of July and August. In the work of detection, he must be on duty continuously day and night. As a smokechaser,

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5/ A smokechaser is a man to whom is assigned the responsibility for making first attacks. The term "fireman" designates both detectors (lookouts) and smokechasers. The combined duties of detection and smokechasing may or may not be assigned to any particular fireman.

when not away from his station fighting fire, he must keep himself constantly available to receive the report of a fire and in readiness to start immediately with proper equipment. These conditions preclude the possibilities of normal community and family associations. No provision is regularly made for shifts to relieve the fatigue of continuous duty, or for recreation.

Although employment practices have been directed toward obtaining the best men easily available, these practices have not prevented the use of a large number of low-grade men. The ultimate establishment of stable local populations, dependent upon growing and harvesting forest crops, would help to solve the personnel problem. Until such sources of labor become a reality, the regular seasonal personnel might possibly be procured through labor arrangements with distant industries in which activities reach their lowest levels in summer. Men from such sources might be expected to return annually for many years.

With a stabilized force the effectiveness of annual training would be greatly increased.

For purposes of comparison, figure 2 shows the burned areas of worst seasons, the year-long man power annually available for fire duty, and the training given annually in the duties of fire control. Dotted lines suggest trends that appear to be consistent with an attempt to bring burned area to the allowable level by the year 1940. (It is shown later in the discussion of acreage burned per year that burned area is a problem of worst seasons only.)

When training falls off rapidly, as it did after 1930, for a few years some of the trained men return to work and some of these remember their training. In graph *C* of figure 2 it has been assumed that the influence lasts two years. A similar assumption, not shown, applies to numbers of men available as shown by graph *B*.

With these considerations in mind it will be noted that while year-long personnel and training increased to 1930 maxima and dropped, worst-season burned area decreased consistently to a 1931 minimum and then sharply increased. Other influences on burned area whose functions and trends are closely related to sufficiencies of year-long personnel and training, are supervision, inspection and training of men at point of duty.

In final analysis, efficiency can be proved only by the organization's ability uniformly to perform its functions with a degree of rapidity that approaches the highest demonstrated to be possible. These operations are discovery, report, getaway, travel, and firefighting. (Records of annual accomplishment for each of the western forests of Region One are shown later in Part III. Annual averages for this group of forests are shown later in figures 10 and 11.)

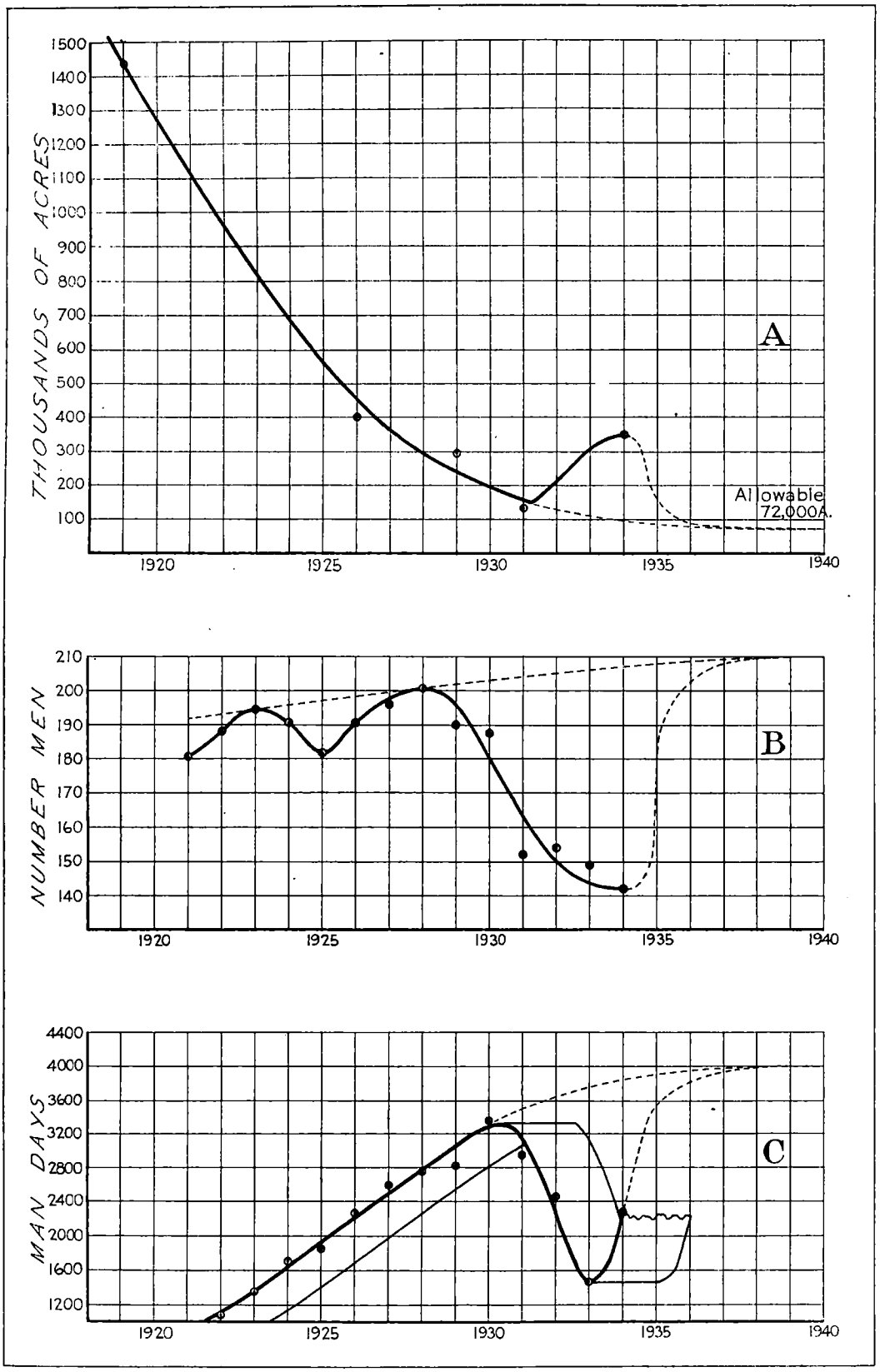

FIG. 2 BURNED AREA AND TWO IMPORTANT INFLUENCES

A- AREA BURNED IN WORST SEASONS ONLY

B- YEAR-LONG MAN POWER AVAILABLE FOR FIRE DUTY
Includes regional supply men and one chief clerk per forest

C- TRAINING GIVEN IN FIRE CONTROL
For duties of fireman, foreman, and ranger
Width of ribbon represents two years duration of influence

REGION I WESTERN FORESTS

Study of the erratic performance of these operations in spite of the continuous developments in numbers of men, their placement, and facilities for action (shown later by figures 8, 12, and 13) indicates that the burned-area objectives will not be reached at the present levels of action.

After the existence of a fire is known, travel consumes part of the time available for control, and work at the fire consumes the remainder. Hence, allowable travel times are dependent upon rates of work that will be put into effect after arrival. Average rates of work have been so low that unwieldy numbers of men and excessively short travel times would result from accepting them for the future. Higher rates, demonstrated by the better classes of employees, have been used in forecasts applied to the work of planning. Carrying out the plans outlined here will not accomplish the expected results until travel times and rates of work have been brought within the specifications used in planning.

FUELS, AND A FUEL-REDUCTION PROGRAM

An important regional characteristic is that fires, of any size, kill most of the trees within their borders. Mature ponderosa pines provide a partial exception, frequently surviving grass fires; and a few old larches per acre, in scattered patches, usually survive crown fires.

The typical landscape for 20 years after the first burn of a mature stand resembles the home anchorage of a sailing fleet. These snag areas, and "blowdown" areas, constitute peak load problems.

Fuels so heavy that the most powerful attacks are sometimes ineffective exist over large areas of single burn. In their worst form these fuels are the remnants of decadent stands of 75 to 150 trees per acre killed by crown fires that consumed only the twigs. Within 10 years, tangled intermixtures of reproduction, snags, and broken windfalls usually develop. After another 10 years these change slowly into easier fuels as snags fall, and new stands overtop the masses of rotting debris. Average fuel conditions are approached 40 to 60 years after the fires.

The absence, almost everywhere, of single-burn refuse in stands older than 80 years indicates that such debris has commonly been consumed by fire before new stands were able to grow to maturity. Strong support for this theory is found in the many failures, during the past 20 years, of efforts to prevent vast areas of first burns from being reburned by immense single runs of fire. Apparently a program of fuel reduction will be required if large first burns are to be prepared for satisfactory fire control.

On numerous occasions in single burns, while a smokechaser was felling a single large snag on fire in a light breeze, a disastrous spread to other snags and to ground fuels has resulted from flying sparks. The job presented in such circumstances to a light reinforcement crew, arriving 1 to 3 hours after call for help is made, can hardly be exaggerated. Instead

of one snag on fire, ten or more should be expected, each requiring 1 man hour to fell it, and the tangled ground fuels normally are full of sparks and fires in various stages of development.

For large fires the rapidly advancing fronts of which are producing intense heat, frequently the worst fuels are those left by single burns in the bottoms of small valleys where growing conditions are most favorable and where sufficient water for fire pumps flows continuously. Fires usually die down as they run downhill out of the wind; but if there they encounter the fuels that are the worst possible for creating strong new convection currents carrying thousands of large sparks onto the next ridges, increased momentum is given them in the very places where they could best have been fought if those fuels had been removed. The expense of converting hundreds of these fire traps into firebreaks would be high, but possibly not so high in the long run as the alternative costs of suppression and of damage caused by conflagrations. Such conversion is one sure way to eliminate a large amount of burned area.

Almost every large run of fire in a burn takes a toll from adjacent green mature stands. Thus, in addition to exposing vast areas of steep slopes to almost free forces of erosion and making them uninviting to recreationists, it creates new areas of single burn to continue the cycle--mature forest to single burn, to double burn, to very slow regeneration by periodic seeding into the vast barren areas from the mature trees of margins and from advancing bands of young trees as these become old enough to bear germinable seeds.

Lack of preparation in 1910 left an immense inheritance of difficult fuels--single burns. According to rough estimates the area of fuels worse than average increased from 5 percent in 1909 to a maximum of 23 percent in 1931, and is now slowly decreasing.

An important subject for consideration in a fuel-reduction program is the increasing encroachment of cheat grass into abandoned fields and over-grazed ranges adjacent to forests. This grass occupies the driest exposures, and becomes extremely inflammable early in the summer. In many places it forms a connecting link for spread of fires, from roadsides and other places where fires are likely to start, to forests. Its rate of spread is normally so fast that there is little hope of placing smokechasers with travel times short enough to meet the situation.

FIRE-CONTROL OBJECTIVES, AND ACTION REQUIRED

Fire control is one of the more important activities necessary to maintain forest resources in condition satisfactory to the owners, public or private. Protection may be needed for the production of wood or of wild life, for conservation of scenic values, for regulation of water flows, or for other purposes. Determination of what constitutes satisfactory protection necessitates not only a forecast of the requirements of

local and distant consumers, and forest users, but also an estimate of the toll taken by destructive agencies other than fire. Considering the lack of knowledge in the many factors involved, it is neither to be expected that a definite and changeless objective could be determined in a short period of years, nor that a specific objective would be applicable everywhere. A general objective applicable everywhere through evaluation of existing factors was the first one developed. This has been called the "Economic," "Least Cost," or "Least P + S + D" objective.

ECONOMIC, OR LEAST P + S + D OBJECTIVE

The essential features of this objective are, that damage, "D," is expressed in terms of money value, and that damage is regarded as one of the costs of fire, the other items of cost, "P + S," being incurred for control measures. The letter "P" represents expenditures for presuppression (including prevention) and "S" represents expenditures for suppression. Up to a certain point increases in costs of preparedness and fire-fighting, "P + S," are more than equally repaid by reductions in damage "D." Expenditures could, however, be increased to such an extent that the total of expenditures and damage would be unnecessarily great. This objective aims at applying the degree of fire control that produces the least total of "P + S + D." That this theory is sound can hardly be questioned. The difficulty of application lies in evaluation of the item "D." Appraisals to be correct must include considerations of erosion, water regulation (for floods, irrigation and hydro-electric power), recreation (including scenery, fish and game), and general forest influences on climate, and on stabilization of forest communities, not for one year but for the duration of the damage. The difficulties are obvious. Even if the evaluation of damage had not proved elusive, cost statistics would be lacking from which to show how much reduction of damage was accomplished by a given increase in fire-control costs. The most economical division of cost between presuppression and suppression is open to argument.

In 1928 Flint *(6)* published Forest Service statistics for this Region, covering trends since 1910 in the relations between the three factors of this objective. He concluded that total cost plus losses would be most economical when 2.2 cents per acre were expended for presuppression. If the conflagrations of 1926 were left out of the calculations, he found that presuppression costs should be 1.35 cents per acre, but if seasons of very severe burning conditions were to occur more frequently (as they have since he made his computations in 1928), expenditures for presuppression even greater than an average of 2.2 cents per acre would produce the most economical total of "P + S + D."

Even if these conclusions were acceptable guides, it would still be necessary to adjust the long-period average by increasing presuppression expenditures during seasons of most severe burning conditions and decreasing them during seasons of less than average severity. Furthermore, the correct distribution of Regional funds to localities would remain to be determined.

How much dependence to place on his conclusions is difficult to determine. Damages were based on changing standards of appraisal, and many appraisals were merely rough approximations. Because future market values are unknown, weights given to accessibilities and ages of stands burned have been erratic and undeterminable. No appraisals have as yet included all items of damage. The evidence seems to be ample, however, to justify the conclusion that much greater expenditures for presuppression are economical.

Flint's computations and conclusions are probably as accurate as any that have been applied to the "Economic" objective. He concluded that "the safest simple index for the distribution of funds is area burned over." The many undeterminable values involved in application of the "Economic" objective led to adoption of a burned-area objective.

PERMISSIBLE PERCENTAGE OF BURNED-AREA OBJECTIVE

To guide fire-control action during the years while social demands are changing and determinations of facts are clarifying issues, a temporary standard *(22)* of tolerable average annual burned area was adopted for national forests. This statement specified, for each forest type, the maximum annual burned percentage compatible with maintenance of the forest cover over a long period of years.

The relative percentages of burned area allowed in different types were based on relative ratings of damage made by experienced forest officers. The following factors were considered.

1. Timber value - present and potential.
2. Destruction of site value by fires.
3. The difficulty of re-establishing the forest following fires.
4. Creation of future fire hazards, which will prevent the maintenance of the forest itself.

One-tenth of one percent (0.1%) of burned area per year was allowed spruce and white pine types, which are the only ones included in the most damaged class. Allowances for other types of the region are shown in table 4. It was estimated that within the limits of such losses intensive timber management can be carried out.

For watershed values allowances varying, with damage and intensity of use, from 0.4 to 1.2 percent of area burned per year were specified. The percentage of allowances applicable to particular watershed values existing in the region have not been worked out.

The formulators of this objective did not provide burned area allowances for recreation values, which in certain areas are obviously higher than the highest wood-products values. However, it was recognized that where high values are at stake, a smaller burned area than the

specified allowance might prove to be the most economical, considering all items of cost and damage. Thus, provision was made for applying the "Economic" objective, previously discussed.

It should be pointed out that an amount of burned area cannot, correctly, be called "permissible" unless it is that amount which results from the most economical total cost of control expenditures plus damage. Hence, if all items of damage within the burned area allowance were accurately appraised, their total should conform to the objective of "Least P + S + D" and the two objectives would be the same. Since the allowances are maximum amounts that can be tolerated, the word "tolerable" more correctly describes them than "permissible," the word originally applied.

Table 4.--*Forest-type areas in western forests of Region One: totals existing, totals burned in 1921-30, and total burns permissible.*

Forest type	Area					
		Burned over in 10 years				
	Total 1/	Actual, 2/ 1921-30	Permissible 3/		Relation of actual and permissible	
					Over	Under
	M acres	M acres	M acres	Percent	M acres	M acres
Western white pine	2,116	300	21	1.0	279	
Ponderosa pine	1,307	65	26	2.0	39	
Lodgepole pine	4,172	131	417	10.0		286
Larch-Douglas fir	3,101	211	78	2.5	133	
Douglas fir	1,331	26	40	3.0		14
White fir-cedar	545	55	11	2.0	44	
Cedar-hemlock	85	11	2	2.0	9	
Spruce	641	16	6	1.0	10	166
Subalpine	2,566	142	308	12.0		58
Brush and grass	333	25	83	25.0		
Total	16,196	982	992	6.1	514	524

1/ Gross, exclusive of 344,785 acres barren and cultivated.

2/ Annual figures were totaled regardless of area overlap.

3/ Permissible according to report of Washington Conference of Regional Foresters, 1930, applying the allowances specified for timber management.

For the western national forests of Region One the relation of burned area to total area and to the permissible-burn-objective for the period 1921-30 is shown in table 4 for each of the forest types present. (Similar data are shown for each of the individual forests in Part III.)

The overburn of 514,000 acres was caused by 82 fires out of 12,056, less than 1 percent of all fires. In other words, a few conflagrations caused 2 to 14 times as much burn as is permissible in the timber types of highest value, in spite of the fact that 99 percent of all fires were satisfactorily controlled.

The intermixture of types makes it probable that efforts, which evidently are needed to reduce burned area in the overburned types, will proportionately decrease that in the already underburned types as well. Hence, the permissible-burn percentages set up for the underburned types no longer have any practical significance, and in the following calculations only overburned types are considered.

The 1921-30 ratio of 10-year burned acreage in all types to that in the overburned types alone was 1.5 to 1. The permissible 10-year allowance in types now overburned is 144,000 acres. If the 1.5 to 1 ratio continues through the period 1931-40, the 10-year total burn for all types, by direct proportion, should not be allowed to exceed 216,000 acres. Approximately all of this may be expected to burn in three or four seasons that will probably be classed as "worst." Burned area is insignificant except in "worst" seasons, two of which (1931 and 1934) have already occurred. Using the conservativ probability of three "worst" seasons in the 1931-40 period, the average burned area of one "worst" season should not be allowed to exceed one-third of 216,000 acres, or 72,000 acres. The area already burned, 1931-34 inclusive, is 497,5000 acres, which averages 249,000 acres for each of the "worst" seasons 1931 and 1934. Hence, the whole burned-area allowance for the 10-year period has already been greatly exceeded in the first 4 years, and the average burned area per "worst" season is 3.5 times that permissible.

Attention is directed to the use here of burned-area allowances based entirely on the timber management specification of the objective. Actually considerable portions of the areas burned lie in the zone now classified as permanently non-merchantable, to which the more liberal burned-area allowances of watersheds should be applied. On the other hand, it is not at all unlikely that the 1931-40 period will contain four "worst" seasons instead of the three used in the estimate, in which event the burned-area allowance will probably be further exceeded.

It is doubtful that a closer estimate of the situation could be made. The accuracy of the present estimates is ample to support the statements that burned area continues to be highly unsatisfactory and that action in all phases of fire control must be much faster, stronger, and more efficient before the permissible burned-area objective needs to be subjected to refined scrutiny.

A high degree of chance in several factors enters into the probability of attaining this objective. These factors are number of large runs that occur over a long period of years, number of fires that die down enough to permit control before they reach excessive size, and the places, in relation to intermixtures of types, where errors of action or unusual weather result in large runs. In the northern Rocky Mountain forests this objective is not tangible except for long-period post-mortem examinations.

OBJECTIVE OF CONTROL WITHIN THE FIRST WORK-PERIOD

When all 1921-30 fires were arranged in size classes and the corresponding average speed and strength of attack determined, it was found, on the basis of averages, that the better the action was the greater was the area burned. This apparent inconsistency is caused by analyzing the facts from the wrong viewpoint, that is, by failure to segregate records of action according to prevailing severity of burning conditions, and according to fuels. Anyone familiar with the usual practice of placing men closer to the worst fuels than to easy ones, when burning conditions are worst, knows that large acreages of burned area accumulate in spite of fast, strong action. Very few of the 16,000 individual fire reports accumulated since 1920 tell how severe the burning conditions were at the fire, and none records fuel conditions in terms specific enough to indicate what speed and strength of attack is needed for success in a particular fuel.

If sufficient information were available, useful multiple correlations probably could be worked out between the five variables severity of burning conditions, character of fuel, speed of attack, strength of attack and area burned.

For the reasons given, failure must be admitted in endeavoring to obtain, for the forest types of this region, correlations between burned area and speed of attack similar to those reported by Show and Kotok *(19)* for the forest types of California. In the northern Rocky Mountain region, such correlations could not be restricted to man-caused fires as were those of Show and Kotok: in this region lightning fires constitute 70 percent of all fires and cost about the same, in the total, as those caused by man. Speed could not be measured from hour of ignition, because 20 percent of lightning fires are not discovered within 24 hours and some smolder unknown for more than 10 days. Even for man-caused fires, especially of the camper and debris-burning classes, the hour when spread began is more significant than that of ignition.

In analyses and plan work for this region, action time has been measured from hour of discovery. This starting point, while open to criticism, is the most definite one available.

In spite of the limitations mentioned, definite indications of required fire-control action are not lacking. Conclusions based on analysis of fire records by Gisborne and Hornby 6/ are as follows: Past overburn was all caused by a few large conflagrations; almost every spot in the region must be suspected as a possible starting point; and the objective of permissible-percentage-of-burned-area will probably not be attained if any fire larger than 4,000 acres is permitted. In each of the five forest types assigned the lowest percentages of permissible burn, the sum of the areas burned by all fires smaller than 4,000 acres equaled the permissible burn. Although in other types fires larger than 4,000 acres did not cause overburn in 1921-30, the intermixture of types and man's well-demonstrated

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6/ Fire-Control Objectives and Practices in the Northern Rocky Mountain Region, 1931. Unpublished.

inability to stop fires at any particular size or place make it necessary to conclude that there, also, no larger fires can be permitted intentionally. The conclusions are further substantiated when attention is focused on areas smaller than the entire region, regarding them as the entire forest to be protected, such as sustained-yield working circles and natural units used for recreation or water regulation.

After the heat at the front of an aggressive fire becomes too great to permit work, only a remarkable change of conditions there makes it possible to prevent unlimited spread. Effective changes may be in fuel, topography, wind, or moisture. Under such conditions, argument whether the allowable size is 4,000 or 400 acres appears irrelevant. The opportunity to limit spread is before a fire makes its first aggressive run. The next opportunity comes after the fire dies down (usually at nightfall) and before it makes another run during the next mid-day burning period. This means that under the most severe burning conditions detection and first attack must aim at preventing the escape of any fire. Failing this, reinforcement attacks must be planned to stop all spreads as soon as heat and advancing fronts permit. Another definite way of stating approximately the same objective is that when burning conditions are critical detection, first attack, and reinforcement action must be planned to catch every fire in the first work period. This period ends when the next mid-day burning period begins, usually between 9 and 12 a.m. This is a tangible guide of action rather than a post-mortem check on accomplishments. It is the objective applied to plan work discussed here.

CONSIDERATIONS IN APPLICATION OF OBJECTIVE

Influence of Intense Action on Cost, Damage, and Area Burned

Under certain conditions least cost of fire control plus damage is obtainable by applying a high rate of suppression work, thereby completing the job in a short time. One of these conditions prevails in localities where large numbers of men are available without regular cost to maintain them. Figure 3 shows, for fires attacked at various sizes, the intensity of attack, the length of suppression time, the average suppression cost, and average acreage burned per fire. This figure includes all fires, within the indicated range, that occurred in Region One during the 10 years 1921-30. For all fires controlled within 36 hours, regardless of initial size, it is evident that the stronger and faster the action the less was the cost as well as the acreage burned. For fires that lasted beyond 36 hours the data are erratic; influences affecting these cases include fatigue, deferred attacks, weather and fuels prevailing during the second and later work periods.

When an attempt was made to plot comparable data to that shown by figure 3 for the period 1931-33, inclusive, it was found that the greatly increased intensity of action practiced could not be justified on the basis of suppression costs alone as was the case for the average of the 1921-30 period. For fires suppressed within any given length of time the average cost per fire since 1930 was found to be 2 to 10 times as great as before.

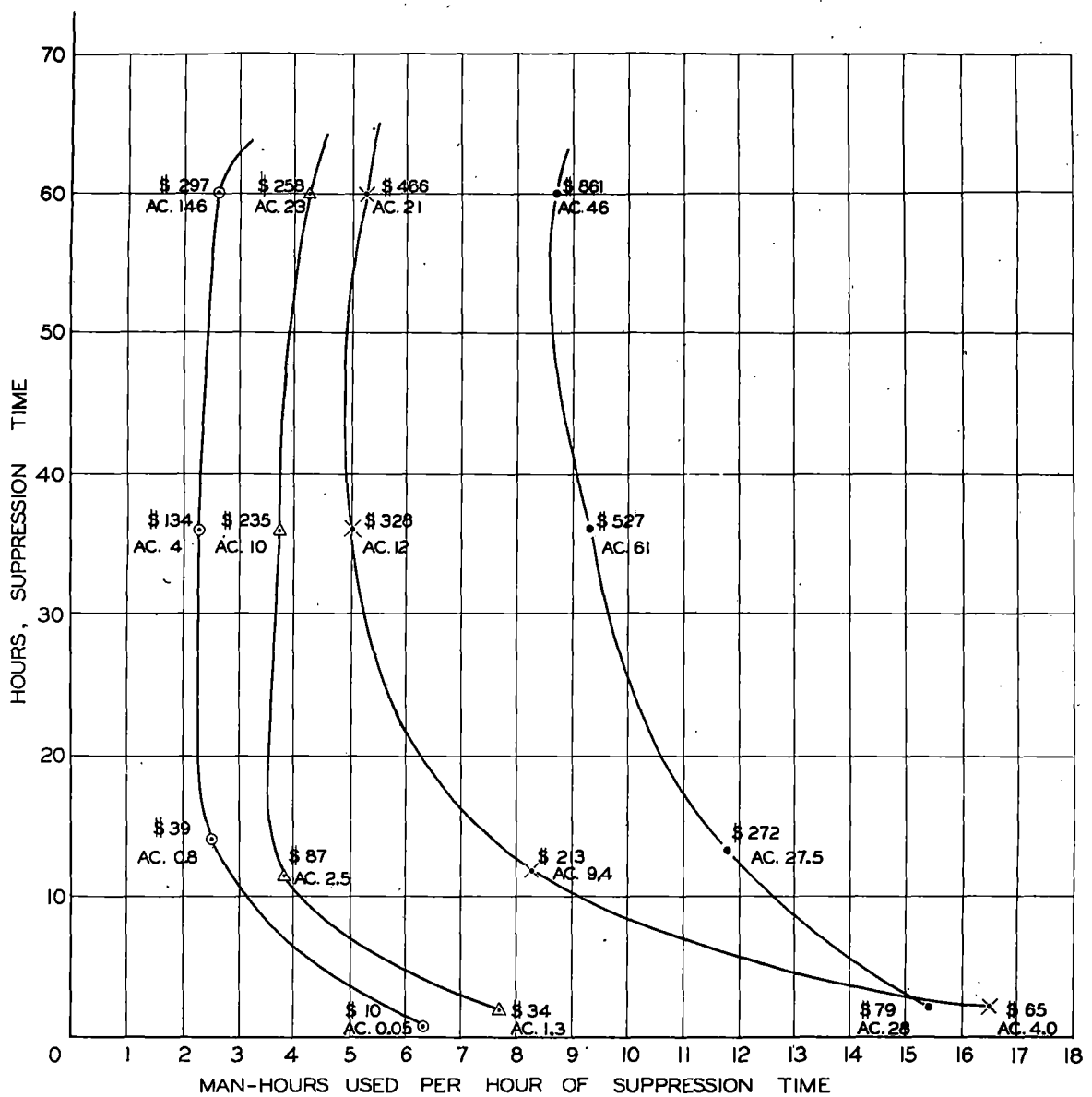
HOURS, SUPPRESSION TIME
MAN-HOURS USED PER HOUR OF SUPPRESSION TIME
$ 297 AC. 146
$ 258 AC. 23
$ 466 AC. 21
$ 861 AC. 46
$ 134 AC. 4
$ 235 AC. 10
$ 328 AC. 12
$ 527 AC. 61
$ 39 AC. 0.8
$ 87 AC. 2.5
$ 213 AC. 9.4
$ 272 AC. 27.5
$ 10 AC. 0.05
$ 34 AC. 1.3
$ 79 AC. 2.8
$ 65 AC. 4.0

FIG. 3. INFLUENCE OF INTENSITY OF ATTACK ON SUPPRESSION TIME AND ON AVERAGE COST AND ACREAGE PER FIRE.

SIZE OF FIRE WHEN ATTACK WAS BEGUN

⊙ 0.00 — 0.25 ACRES
△ 0.26 — 1.00 ACRES
X 1.01 — 5.00 ACRES
● 5.01 — 20.00 ACRES

FIRES OF 1921 - 30
REGION 1 WESTERN FORESTS

Although the annual trend has not been examined, an abrupt increase in intensity of action is known to have begun in 1929. The question arises; was the resulting reduction of damage great enough to justify this higher average cost per fire?

In table 5 are shown the number of fires, their total suppression costs, and the area burned in each period. In order to make possible a comparison of equal numbers of fires in each period, the cost and burned area of 2,786 fires, at the 1921-30 average per fire, are shown. The percentage of severe fire seasons was approximately the same in each period.

If damages in the burned area were appraised at $1 per acre, it will be found by addition of burned acres to suppression costs, that the comparative total "S + D" costs are $208,575 in favor of the less intensive action represented by the average in effect for 1921-30, inclusive. But if damage were appraised at $5 per acre the "S + D" total costs would be $9,229 in favor of the more intense 1931-33 actions. It would not be legitimate to draw refined conclusions from this rough evidence. However, the conclusion appears to be amply supported that whenever a large supply of man power is available the most economical action is to send as quickly as possible to every fire enough men to insure that every part of the perimeter will be placed under control before worse weather conditions are encountered.

In table 6, more detailed comparisons are made between comparable data of the two periods. It may be confusing to note that although the average size of all fires has been greatly reduced in recent years, a larger average size occurred for every length of suppression time. A clearer way to state the case is that any size of fire has been corralled in a shorter time in recent years than formerly. Until analyzed, the larger average size during recent years in the longest suppression time class, four or more days, may still be perplexing. In recent years almost no small fires got into this class. The average size shown, 2,160 acres, is derived from a few large fires, 28 in three years, or an average of nine per year. In the former period, since many small fires got into this class, the average size shown, 1,360 acres, is derived from both small and large fires, the total number being 339 in 10 years, or an average of 34 per year.

The lower the probable damage, the more difficult it becomes to make a clear showing in favor of high control costs. It also becomes more difficult to determine a desirable division of control costs between preparedness and suppression. The degree to which preparedness expenditures for fast reinforcement action could economically be increased is determinable only by trial. In table 6 there is a strong indication that the average reduction in burned acreage per fire is as closely related to quick and strong initial attack as to later action. In comparing the percentages of fires in each suppression-time class for the two periods it will be observed that 15 percent more fires were suppressed in the 0 - 1 hour class in 1931-33 than in 1921-30; in fact, the 0 - 1 hour class is the only one in which a gain was made in 1931-33. Obviously the change that occurred was removal of fires and larger burned areas from each of the longer suppression-time classes to some shorter one. Since first

Table 5.--*Numbers of fires, suppression costs, and acreages burned on western forests of Region One in 1921-30 and in 1931-33.*

Item	Number of fires	Total suppression cost, in dollars	Total acreage burned
1921-30 total	10,252	2,447,933	524,019
1931-33 total	2,786	928,880	87,914
Expected total for 2,786 fires according to 1921-30 averages per fire	2,786	665,854	142,365

Table 6.--*Suppression time and costs, and acreages of fires* 1/ *on western forests of Region One in 1921-30 and in 1931-33.*

Suppression time 2/	Percentage of fires, in total number		Average cost, in dollars, per fire		Average acreage burned per fire	
	1921-30	1931-33	1921-30	1931-33	1921-30	1931-33
0 - 1 hour	41.1	55.8	9	18	0.3	0.4
1 - 4 hours	29.4	26.4	23	59	1.0	2.3
4 - 12 "	13.8	10.5	68	223	10.6	11.7
12 - 24 "	5.9	4.0	148	732	9.2	30.8
1 - 2 days	3.8	1.3	336	2,842	26.5	106.0
2 - 3 "	1.5	0.6	742	5,244	69.7	579.1
3 - 4 "	1.1	0.3	1,357	7,241	146.9	554.6
4 - "	3.4	1.1	5,160	16,400	1360.0	2160.0
Total or average	100.0	100.0	239	333	51.1	31.5

1/ On which first action was taken by Forest Service.

2/ Elapsed time from work begun to fire corralled.

attack is primarily involved in the 0 - 1 and 1 - 4 hour suppression time classes, it appears probable that quicker and stronger smokechaser action than has yet been practiced will do at least as much to reduce burned area as increased reinforcement action. However, the latter is also necessary, and indications are that its sphere of activity should be expanded by taking action on more small fires.

General

After study of errors, rates of spread, fuels, and other influences on the larger fires of the period 1921-30, inclusive, the conclusion was reached that a considerable number of them would have escaped even from the stronger and faster initial attacks and light reinforcement attacks specified in present plan work. No doubt occasional conflagrations, impossible to control within the first work period, would occur under a degree of preparedness so expensive as to be clearly uneconomical. When burning conditions are at the other extreme, minimum, man-power stations are frequently so widely separated that control of remote fires within the first work period is impossible. Since it is most economical to permit longer control times then, these fires might be called legitimate extra-period fires. Another cause of extra period fires is error. It is estimated that these three factors will prevent at least two percent of all fires from being controlled within the first work period. Specifications used in plan work were intended to permit the control of all other fires, approximately 98 percent, within the first work period. The percentages of fires that became extra-period in the years 1931-35, inclusive, are 5.6, 4.3, 6.7, 8.7, and 4.7 respectively.

It must be understood that any action requirement stated here applies only to areas where the objectives, the forest types, and the fire histories are as specified. If the objectives were modified for part of the region, allowing more burned area per type, less fire-control strength would be required there. On an area occupied by a forest type in which fires do not make large single runs, or make them very rarely, larger fires could be allowed and hence less strength of fire control might be required. Provision of a regular paid organization for detection or for initial attack might be unnecessary, as is the case in some forests of eastern Montana.

The form of fire-control organization and the capacity required are local considerations determined by the objective and by fire danger as indicated by fire history.

OBJECTIVE ADOPTED IN PLANNING

Attention is directed to the fact that no conflict exists between the three major objectives of fire control that have been widely recognized. Consequently, for planning purposes, the following composite objective was used. By attempting to "Control every fire in the first work period," it is hoped to keep burned acreage within the "Permissible-percentage-of-burned-area," and ultimately to make the sum of fire-control costs and losses most "Economical."

PLANNING THE FIRE-CONTROL SYSTEM

SERVICES NECESSARY

Before attempting plan work it is necessary to study the different activities that influence burned area. A list of fire-control activities considered necessary follows. For each of those over which he has no control the planner must determine its importance and trend and assume some level of efficiency for the future.

FIRE PREVENTION

A degree of effectiveness equal to that now in effect was assumed in planning.

PERSONNEL MANAGEMENT

Procurement, training, supervision, and inspection.

Evidence already discussed (and considered later in connection with figures 10 and 11) strongly indicates that reasonable success and economy demand an increase in personnel efficiency. Rates of work higher than the average of the past have been assumed in determining allowable travel times and strengths of attack.

FIRE-DANGER FORECASTING

Increased efficiency through research is assumed.

ACTION ON FIRES

First Line of Defense

Detection (lookouts)
Initial attack (smokechasers)

Second Line of Defense

Small mobile reinforcement crews

Their bases are communities, landing fields, and other stations.

Heavy reinforcements

Their bases are cities with 100 or more emergency fire-fighters available on call. Since airplanes cannot satisfy travel-time requirements at night, this service is dependent upon a road system.

The four services of action on fires are given equal weight. A planning procedure has been developed for each, and percentages of area covered by each have been worked out.

FUEL REDUCTION

Elimination of the most difficult fuels is discussed on page 15.

RESEARCH

Increase in effectiveness through an expanded program is assumed.

LOADS FOR WHICH TO PREPARE

After study of all the information available, the conclusion has been reached that a system planned to control approximately 98 percent of all fires within the first work period after discovery will be the most economical, all items of expense and damage being considered.

PEAK LOADS

Since the occurrence of fires everywhere must be expected, the most difficult fuels, already discussed, constitute one form of peak load. Conspicuously severe fire seasons constitute another form. The increasing frequency of their occurrence is shown in figure 4, *A*, by a moving number of severe seasons that have occurred per 10-year period.

An accurate definition of the term "worst season" or most "severe season" is impossible, and will continue to be impossible until methods are found and adopted for evaluating and comparing the composite results of such influences as number of days when extremely rapid spread must be expected, continuity of such days, area of prevalence, number of fires, number that occur in difficult fuels, and concentration in number per unit of area according to character of fuel ignited. In such seasons a high degree of drought exists for 4-8 consecutive weeks. Other developments depend upon the frequency of occurrence in "flashy" fuels of high resistance to control and upon the speed and strength of attack applied. Exhaustion is a

conspicuous characteristic in a cause and effect relationship. Man power, including detectors and overhead can stand the strain of continuous work only a limited length of time. After mental and physical exhaustion of the "first string" man power, anything can and usually does happen.

A third form of peak load is caused by high rate of spread continuing for several hours. Continuous rates of spread have averaged as high as 1,600 acres per hour for a 12-hour run. Perimeters produced by the larger single runs have ranged from 30 to 90 miles. Some of the larger runs resulted from the impossibility of making fast, strong attacks; others from failure to do so; a few fires, soon after ignition or discovery, have spread rapidly in spite of quick and strong attacks.

Coincidences of all the most difficult fire-control conditions seldom occur. In the very severe season of 1926 lightning started 109 fires on July 12 and 37 more on July 13, within the Kaniksu National Forest, which then had a gross area of about 700,000 acres. Examples of still higher daily concentrations on smaller areas are 30 fires on 100,000 acres and 15 on 10,000. A daily concentration of 30 to 70 fires per million acres is not uncommon.

Using 10 or more new lightning fires as a peak daily load on any national forest, figure 4, *B*, shows the number of peak loads that occurred inclusive, on the western national forests of Region One during the July-August period of each of the years 1921-30. The 124 peak-load days of the five-year period 1926-30 constitute an increase of 91 percent over the 65 that occurred during the previous five-year period.

Figure 4, *C*, shows that the average number of fires per peak-load day has increased rapidly.

Peak-load days and number of fires for each national forest are shown graphically in Part III. These graphs show that peak loads usually occurred on the same day on several adjacent forests and occasionally occurred on the same day on all forests, partially preventing inter-change of man power even where roads for quick delivery existed. From 75 to 100 percent of these coinciding fires were stopped at sizes less than one-fourth acre.

In planning, special consideration has been given to areas on which peak daily loads have recurred. Figure 5 shows the areas of the region on which two or more lightning fires per 10,000 acres originated on at least three days of the 10-year period 1921-30. In studying concentrations man-caused fires were ignored, because it was found that no more than three, and usually none, of them originated on any forest on the same date as a lightning-fire concentration. The 10,000-acre unit was chosen because it is conveniently convertible and represents about the minimum acreage over which the man power of one station is responsible for first attack. On the shaded areas shown by figure 5 there is a reasonable probability that at any time during a fire season the man power of any station will have more than one fire to attack on the same day. Identification of these

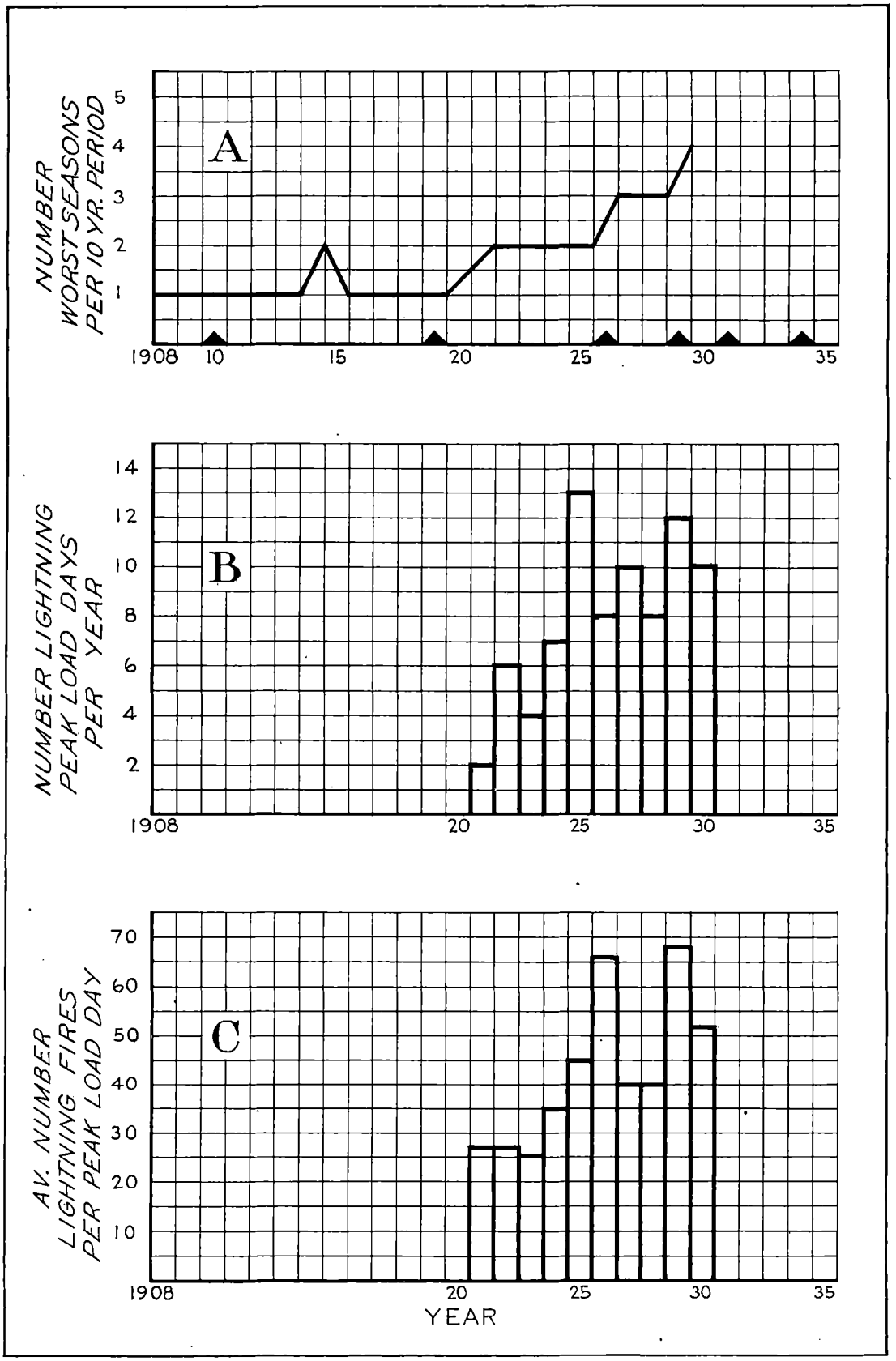

FIG. 4 INCIDENCE OF CONSPICUOUSLY SEVERE SEASONS IN 1908-34 INCLUSIVE AND PEAK LOADS OF LIGHTNING FIRES 1921-30

A-AVERAGE NUMBER OF WORST SEASONS PER 10-YEAR PERIOD (VERTICALLY ABOVE THE DIVISION BETWEEN EACH TWO YEARS, THE AVERAGE THAT INCLUDES FIVE YEARS ON EITHER SIDE IS PLOTTED)

B-NUMBER OF DAYS WITH PEAK LIGHTNING-FIRE LOAD PER SEASON (JULY-AUG.)

C-AVERAGE NUMBER LIGHTNING FIRES PER PEAK-LOAD DAY PER SEASON

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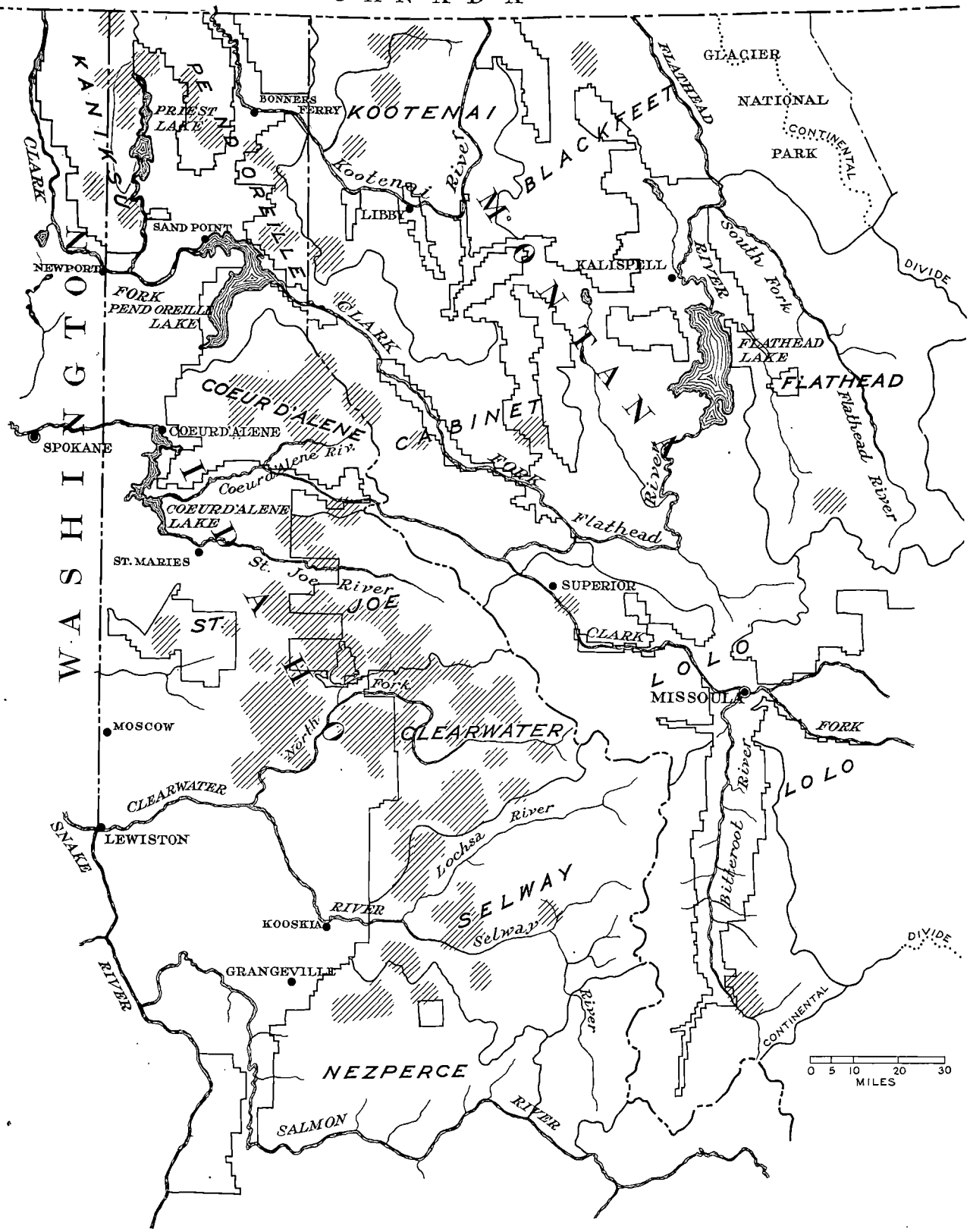

FIG. 5 LIGHTNING - FIRE CONCENTRATION AREAS
AREAS ON WHICH TWO OR MORE FIRES PER 10,000 ACRES ORIGINATED ON AT LEAST THREE DAYS OF THE PERIOD 1921-30, INCL.

areas makes fire control there a lesser problem than elsewhere, because great concentrations are likely to occur almost anywhere and without warning.

Annual and 10-year average numbers of fires per unit of area do not indicate strain. They do, however, show how many times any area has been threatened with fire damage and suppression costs. Where average annual occurrence is high over an area of single burn or blowdown, the satisfaction of requirements there constitutes one of the worst possible peak-load problems.

ANNUAL NUMBER OF FIRES AND AREA BURNED

The number of fires started by man in each year since 1909 and the areas burned in each year since 1920 are shown, under each of the standard classes of cause, in figure 6. These data apply to the western national forests of Region One as a unit whose area has remained approximately the same throughout the periods specified. Similar data are given for each forest in Part III. It will be noted that railroad, debris-burning, and camper fires have only infrequently produced a large part of the total burned area and have shown a continuous decline in number. Other causes have been more erratic. Smoker fires, which have been increasing in number since 1927, seem to demand outstanding consideration in planning.

The annual numbers and burned acreages for man-caused fires, for lightning fires, and for all fires combined are shown in figure 7. It will be noted that the number of man-caused fires declined from 1917 to 1925 and in most of the years since then has approximated the 1925 total, and that the areas burned by man-caused fires increased up to 1929 and thereafter declined. The annual total number of fires, although it has varied greatly, has sharply declined since 1929. The decrease is almost entirely accounted for in the lightning-caused component. Tendencies toward increased concentrations per unit of area are discussed on page 29. Planners are seriously interested in knowing whether this decline will continue or whether, like the decline of 1919-23, it will be followed by a rapid increase.

No pronounced tendency in area burned annually by lightning fires can be stated. This means that the fire-control organization has not gotten the upper hand in the fight. In spite of conspicuous and continuous efforts to get the upper hand, it is necessary to conclude that such efforts did not keep pace with the increasing frequency of serious burning conditions and the rate of accumulation (discussed on page 16) of single-burn fuels.

In figure 7 the graph of total area burned annually shows that the outstandingly severe seasons contributed most of the total. Measures of preparedness must be designed primarily for such seasons. It must be admitted that the classification of seasons as severe is based largely on area burned. Burning conditions may have been equally severe for short periods in other seasons when no fires occurred in worst fuels or none escaped from control.

The consistent reduction of area burned in severe seasons up to and including 1931 constitutes a noteworthy accomplishment, particularly in view of the increase in frequency of peak loads shown by figure 4. The unfortunate increase in 1934 and some of the factors that influenced it were discussed on page 13 in connection with figure 2.

ABILITY TO CARRY LOADS

ANNUAL INCREASES IN FIRE-CONTROL COVERAGES 1/

Owing to increased appropriations, the road mileage and the number of stations manned increased continually after 1910, and the area satisfactorily covered by detection, smokechasing, and reinforcement action increased. Figure 8, *A*, shows percentage of area within the protection boundaries of western national forests seen by detectors of the average-season organization. Figure 8, *B*, shows area reached by smokechasers under travel-time standards now specified (table 12) for burning conditions called "average." The coverages shown by these two graphs for the period 1910-29 should be regarded only as good approximations. The graphs were derived from curves showing coverages obtained when different numbers of stations per million acres are occupied. The stations occupied from 1910 to 1919 were determined in part from the memories of forest officers.

The percentage of area reached by heavy reinforcements within present travel-time standards for their arrival from the bases of man power now used is shown by figure 8, *C*. The geographical limits reached by the routes and methods of travel in use at the end of each five-year period, respectively, from 1910 to 1934 were worked out on maps. Since no allowances were made for delays, the coverages shown are probably greater than the actual.

The data for 1930 and later years shown by each of the three graphs of figure 8 were worked out by methods of planning described later.

The influences of systematic planning on coverages in effect since 1930 are conspicuous. These coverages were accomplished by a redistribution of man power stations, without increasing the number, and by correlation of road construction with location of man power. In 1934 the areas covered by detection and smokechasing were each approximately twice as great as in 1917, and the area reached by heavy reinforcements was four times as great.

The geographical location of developments in heavy-reinforcement coverage accomplished by road construction during the period 1919-33, inclusive, is shown by figure 9. Many of the smaller areas left uncovered in 1933 are reached from roads constructed since then.

1/ "Coverage" means area reached by attackers within travel-time limits, or area seen by detectors.

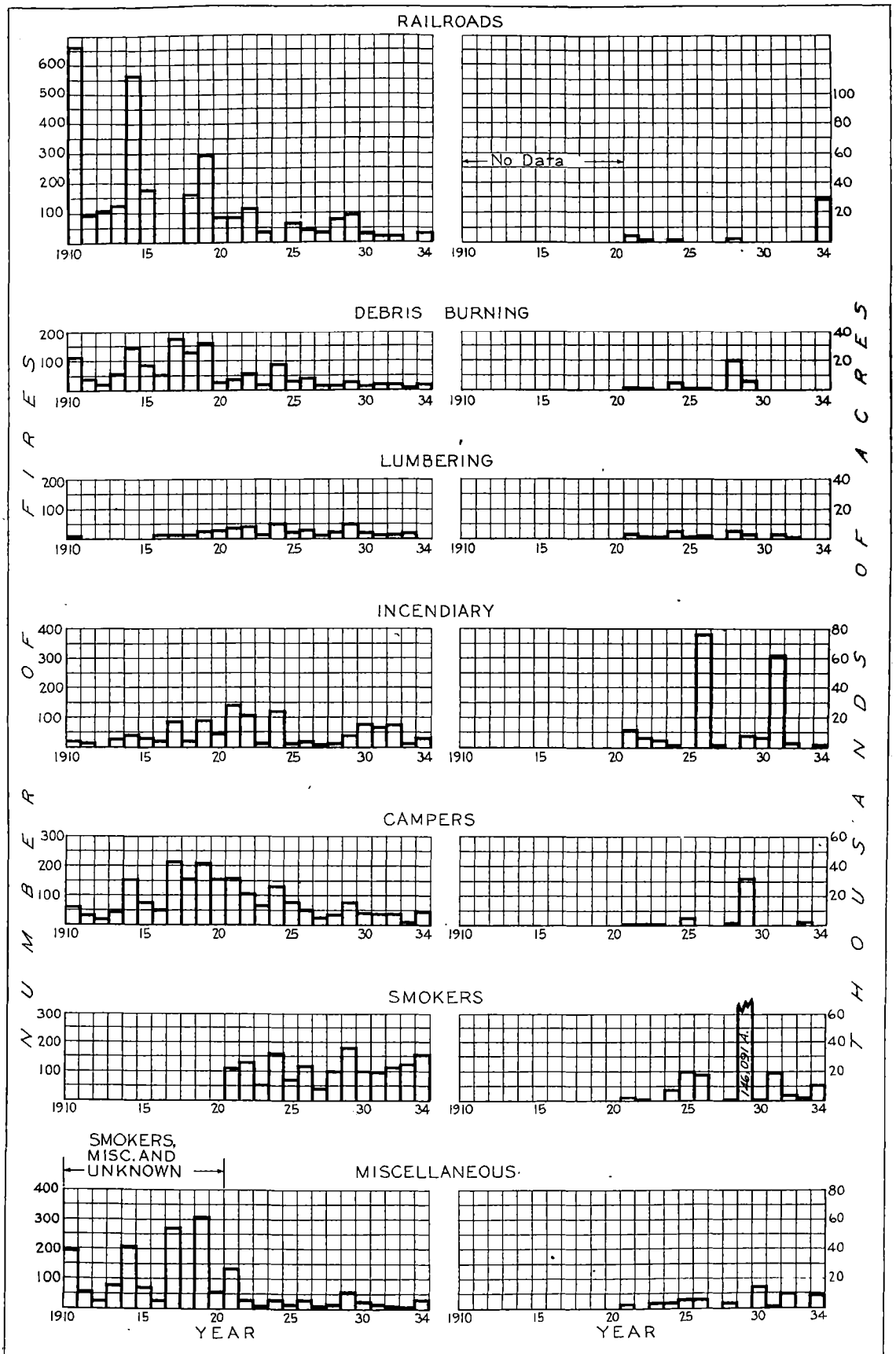

FIG. 6 MAN-CAUSED FIRES
NUMBER, AND TOTAL ACREAGE BURNED, BY CAUSE
IN EACH YEAR OF PERIOD 1910-34 INC.
REGION I WESTERN FORESTS

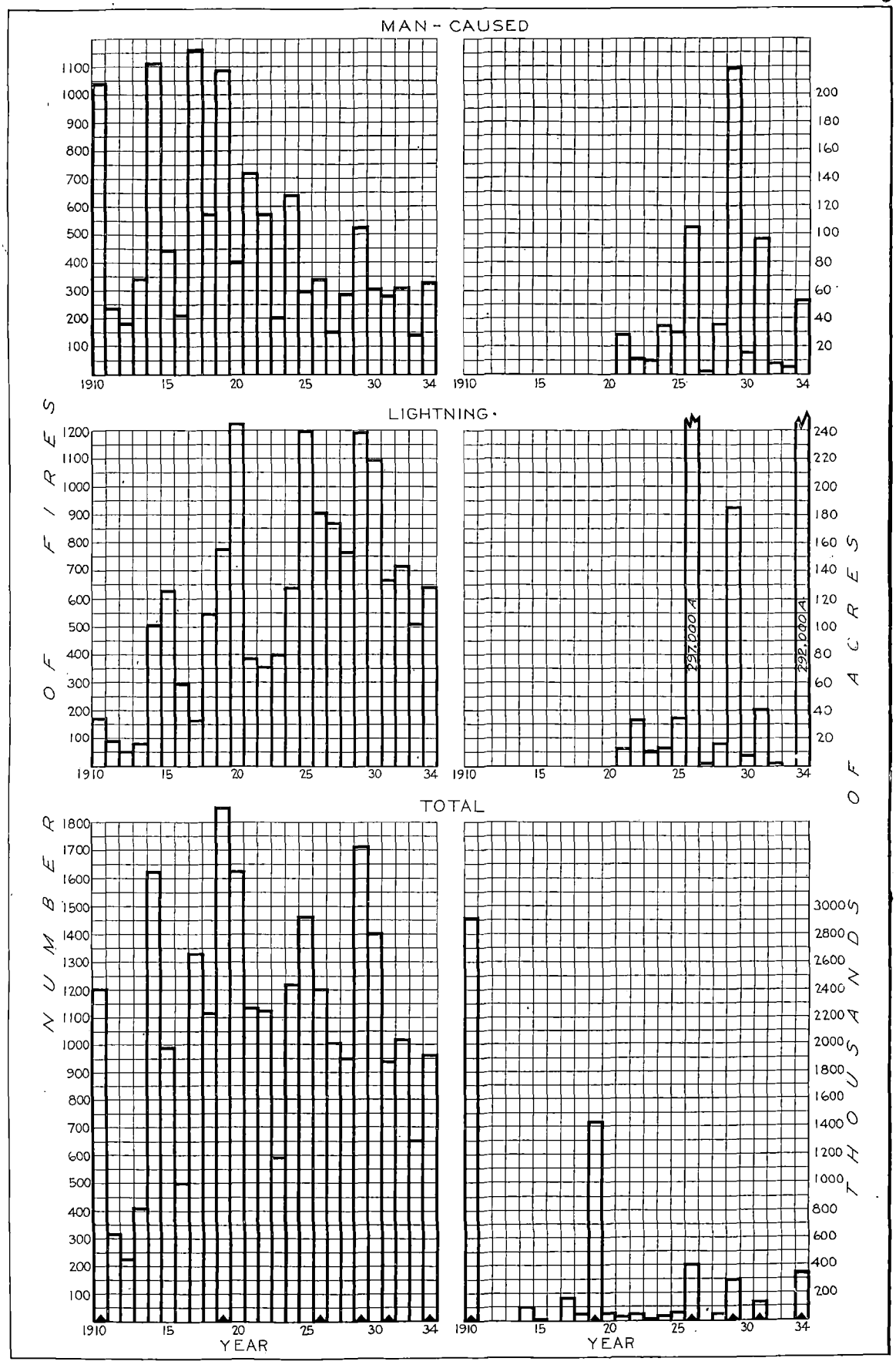

FIG. 7 MAN-CAUSED, LIGHTNING, AND TOTAL FIRES
NUMBER, AND ACRES BURNED PER YEAR
▲ OUTSTANDING SEVERE FIRE SEASONS
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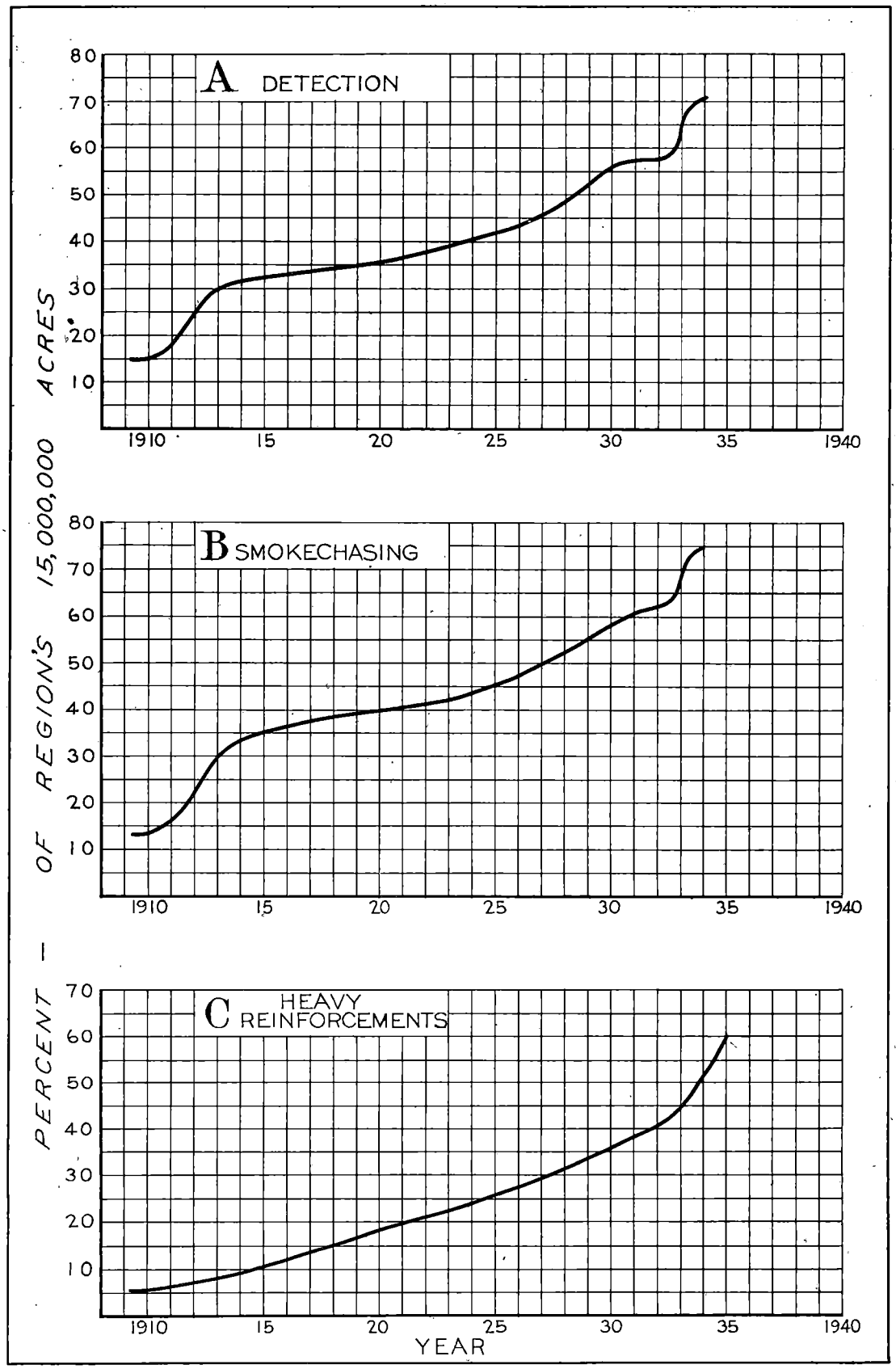

FIG. 8 DEVELOPMENT OF COVERAGES

A - SEEN BY DETECTORS OF AVERAGE SEASON ORGANIZATION

B - REACHED BY SMOKECHASERS, AVERERAGE-SEASON TRAVEL ST'DS.

C - REACHED IN 8.5 HOURS FROM CITIES OF 9000+ POPULATION

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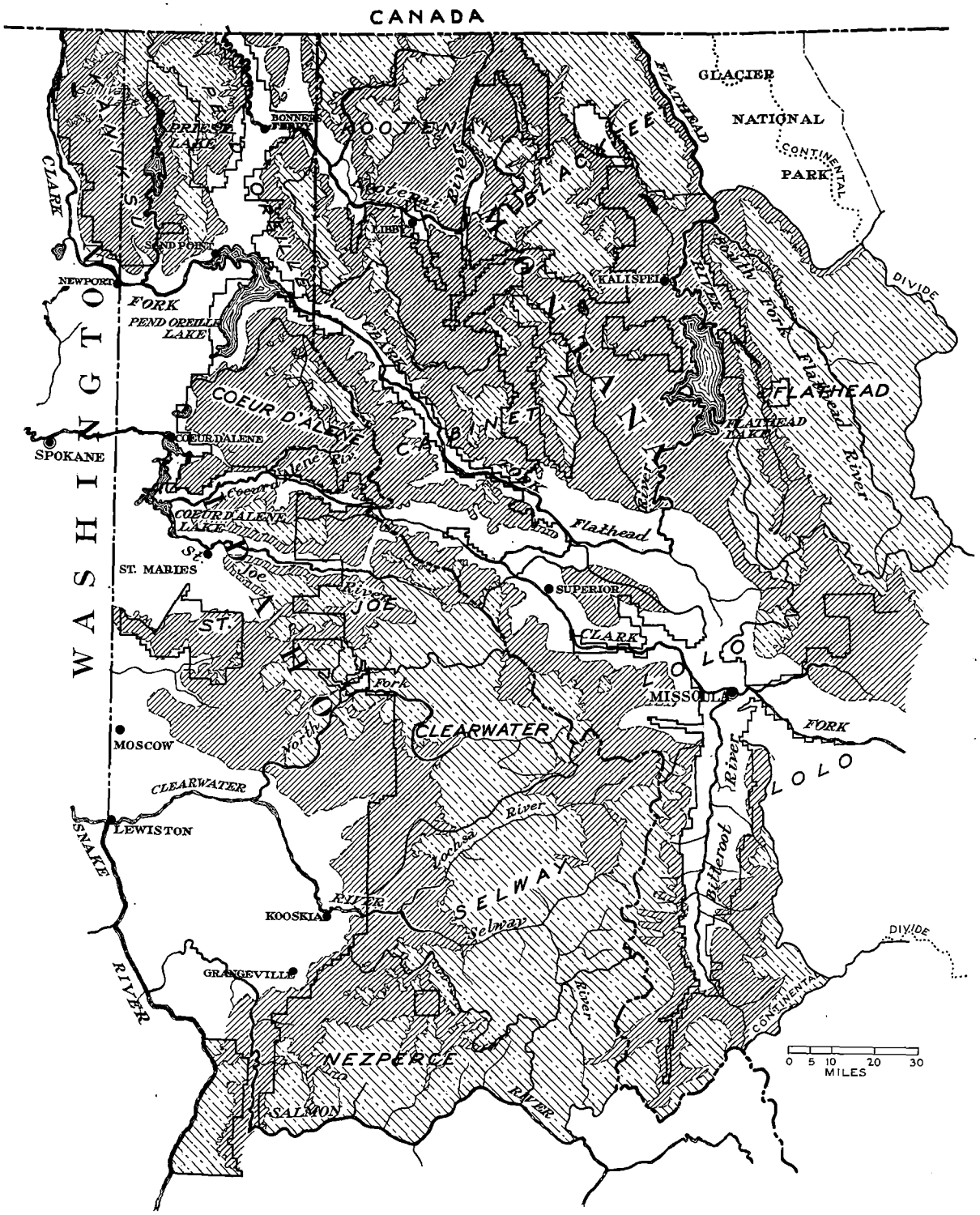

FIG. 9 DEVELOPMENT OF ACCESSIBILITY
1910 TO 1933
ARRIVAL IN 8.5 HOURS FROM BASES —
SPOKANE, LEWISTON, MISSOULA AND GREAT FALLS

Area expanded by road construction 1910-1933.
Area remaining unreached in 1933.

FACTORS OF PERSONNEL EFFICIENCY

Because the effects of an increase or a decrease in the efficiency of man power over a period of years must be recognized in planning, it is necessary to study trends in performance and in factors known to influence personnel efficiency.

Speed of Action

Efficiency of fire control is measured largely by the speed with which fires are extinguished. Trends in speed of action for each of the time-consuming operations of control are shown by figure 10. No explanation has been found for many of the apparent inconsistencies. The 10 percent increase since 1921, in number of lightning fires discovered within one hour, is consistent with the increase of about 50 percent in number of detection stations. Lightning fires, unless seen at the time of strike, are likely to be invisible or inconspicuous for many hours or even days. Get-away time to lightning fires is influenced by high concentrations of lightning strikes per unit of area. Practice has been frequently to defer action on fires in easy fuels, waiting for expected fires to develop in worse fuels. The increase in percentage of lightning fires reached within 2 hours is consistent with road developments in localities little used by people. An increase in percentage of fires controlled within 1 hour after arrival has occurred since 1930, coincident with increases in road mileage and number of smokechaser stations, and with more efficient location of stations. These advantages permitted smokechasers to attack fires at smaller size than was possible before.

After examining these data the only conclusion which can be reached is that whatever progress has been made in fire control has resulted primarily from manning more fireman stations, and from having more firemen, reinforcements, roads, and other facilities. Conspicuous progress in providing man power and facilities tempts the observer to conclude that average efficiency of men has not increased.

Rates of Work

With the exception of the two phases, prevention and detection, fire control organizations exist almost entirely for the purpose of performing a rate of suppression work that is faster than the rate of fire spread. Hence, as much detail of that work as is usable is given here. Considering its importance, one is naturally disappointed to find that very little evidence of work rates according to the factors involved has been collected.

In planning, in dispatching men to fires, and in studying the records of performance it is necessary to recognize that rates of constructing held fire line, per man hour, vary with a great many factors, the more important of which are listed below without regard to order of importance.

1. Fuel resistance to control
2. Method of attack
3. Kind of tools, equipment, and food provided
4. Efficiency of directing officers
5. Training and experience of firefighters
6. Physical and mental ability of firefighters
7. Size of crew
8. Size of fire
9. Aggressiveness and heat of fire
10. Prevailing atmospheric temperature
11. Fatigue
12. Darkness

On individual fire reports and in field studies the influence of each of these factors has not been recorded. Hence, analyses for the purpose of determining relative efficiencies cannot be made, neither can anyone determine to a reasonable degree of accuracy what rate of work to expect of a crew of particular size in any fuel. Individual fire reports show only one of these 12 major factors, fuel, and it is recorded in terms of forest type and age class so general that resistance to control is not recognizable. When an attempt was made to compare rates of work in different seasons, it was found in general that rates of work were lowest in the most severe seasons. These are the seasons in which the largest crews were used on the largest and hottest fires.

A portion of the perimeter of most fires requires little or no work, due to fires dying out and to absence of fuels. For all fires of the period 1921-30, inclusive, the sum of recorded perimeters, on which work was done, was found to be 75 percent of the sum of total perimeters, and this percentage was approximately the same for every size class of fire. If (as was frequently the case) the length of perimeter worked is not correctly recorded, an error is introduced in determining the man hours used per chain of held line.

From the standpoint of fire suppression tactics, the total labor used, or needed, to complete all the work required on a fire may properly be charged against the total fire perimeter to determine the number of man hours per chain. However, only a part of this labor is needed to corral (stop the spread of) a fire, the remainder being used for mop-up and patrol. The efficiency of getting rid of one fire and getting men and equipment quickly reorganized in preparation for the next fire is ommitted from this discussion. Here the important consideration is to get every fire stopped within the first work period, and only the labor used, or needed, up to the point of corralling will be discussed. The labor required up to this stage of completeness determines the number of men to be stationed at different places and the travel time allowed between man power stations and fuel.

During the process of firefighting, it is difficult to know just when a fire will certainly spread no further; hence, the smaller the fire the more likely it is that the smokechaser, or foreman, reported an optimistic corralling time. Not infrequently a small fire is correctly reported corralled at the time attack on it is begun. Reports made for fires

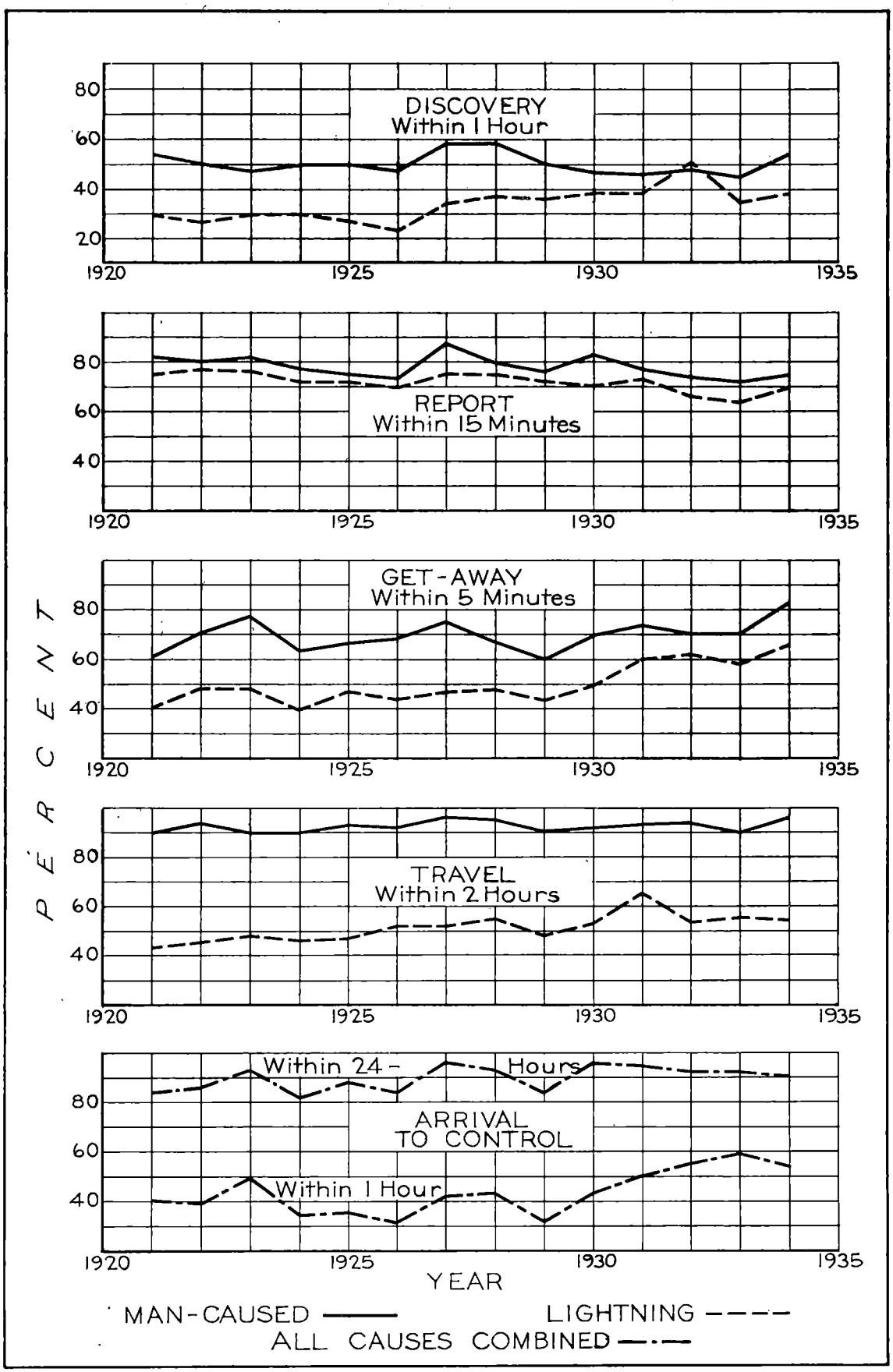

FIG.10 FIRE CONTROL OPERATIONS COMPLETED WITHIN PERIODS INDICATED

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corralled within a few hours contain this element of uncertainty, but they are specific in showing the number of man hours used in construction of held fire line, that is, labor used up to the point of corralling. Since the time of corralling a large fire usually is in the second day, or later, some sectors of the fire had previously been on a mop-up and patrol basis. In reports and analyses considerable and undeterminable amounts of such labor have been included with, and charged against, line construction labor. Evidently the larger the fire and longer its duration the greater is the amount of labor incorrectly charged to construction of held fire line, and the less comparable are average rates of work per man hour derived from the reports. Comparisons of recorded rates of work, disregarding efficiency, should show that they decrease with size of fire. Such a decrease is shown in table 7. Failure to recognize the uncomparability of records frequently has resulted in conclusions that some or all of the 12 factors just enumerated were entirely responsible for the much higher records of efficiency of smokechasers than of crews. The weight of each factor, and all those involved, must be determined before reasonably accurate comparisons can be made.

Table 7.--*Number of man hours used to corral fires on western forests of Region One in 1921-30 and 1931-33.*

Suppression time 1/	Average number of man hours per fire		Average size of fire in acres		Number of man hours per chain of held line 2/	
	1921-30	1931-33	1921-30	1931-33	1921-30	1931-33
0-1 hour	5	2	0.3	0.4	0.7	0.2
1-4 hours	9	11	1.0	2.3	0.7	0.6
4-12 "	34	61	10.6	11.7	0.9	1.4
12-24 "	87	220	9.2	30.8	2.1	3.4
1-2 days	221	961	26.5	106.0	3.4	7.4
2-3 "	559	3283	69.7	579.1	5.3	10.8
3-4 "	922	1539	146.9	554.6	6.1	5.2
4-30 "	3140	3220	1360.0	2160.0	6.8	5.5

1/ Elapsed time from work begun to fire corralled.

2/ Held line was assumed to be three-fourths of the perimeter that corresponds to fire acreage.

In table 7 it will be observed that in addition to controlling any size of fire in a shorter time in recent years than in the former period, about the same number of man hours were used for the same size of fire. Consequently, the number of man hours per chain corresponds roughly with the number of man hours per fire in either period. A considerable gain in efficiency is shown in handling the smallest fires. No other

consistent differences in efficiency are evident. It should be kept in mind that the rates of work are averages. Approximately four times the number of man hours shown per chain have been used, and probably are needed, for each fire size where fuels and burning conditions are worst.

Trends in rate of fire suppression work on large fires are given in figure 11. It shows, according to density of stand, regardless of timber type, average rates of work in the years 1931, 1932, and 1933 combined, and for each of these years separately. These data are based on 102 rough analyses made by men in charge of reinforcement crew work along selected portions of fire lines, most of which were on large fires and during the severe season of 1931. The total man hours included are 147,325, which were used along a total fire line length of 28,900 chains, giving a grand average of 5.1 man hours used per chain for the combined operations of clearing and trenching fire line. For clearing, the grand average is 2.2, and for trenching 2.9. Since the total of 5.1 constitutes only 85 percent of the work done up to the time fires were reported as corralled, approximately 6 man hours per chain of line were used to corrall these sections of fire line. The data could not be segregated for further analysis. In fact, the segregations shown may not include comparable fuels, burning conditions, crew sizes, crew efficiencies, and other unknown influences previously enumerated. Since the data for cut-over areas include only 79 chains of fire line in light fuels, they should be disregarded, or considered minimum.

Because most of the samples of work were collected under the severe burning conditions of 1931, man hours used per chain, under the ordinary burning conditions of 1932 and 1933, accomplished by smaller crews, should be found less, if efficiency were equal. If efficiency increased, a still lower number of man hours per chain should be evident in figure 11. It is necessary to conclude that efficiency as shown by these examples did not increase consistently in the period 1931-33, inclusive. So few analyses were made in the severe season of 1934 that the evidence does not justify conclusions.

With large crews on large fires, where fuel resistances along perimeters vary greatly, the average production frequently is about 1 chain of held line per man day, which is an average of about 12 man hours per chain. After comparing this rate with the 6 man hours per chain shown by the samples of work, just discussed, the 100 percent difference should be discussed. The 6-man-hour figure includes very little work on lost line, not much of the lost motion that almost invariably has been characteristic of organizations at large fires, and all labor was charged to the specific kinds of work performed. The 12-man-hour figure includes considerable work on lost line, and all lost motion. But also important, large numbers of man hours that were used each day, particularly after 2:00 p.m., for mop-up and patrol are included in the average as though chargeable to construction of new line. For these reasons the two rates of work are not comparable. However, the difference is great enough to direct attention to the highly expensive, non-productive, items of lost line and lost motion. Comparable methods of firefighting that could unquestionably be improved were employed in both the

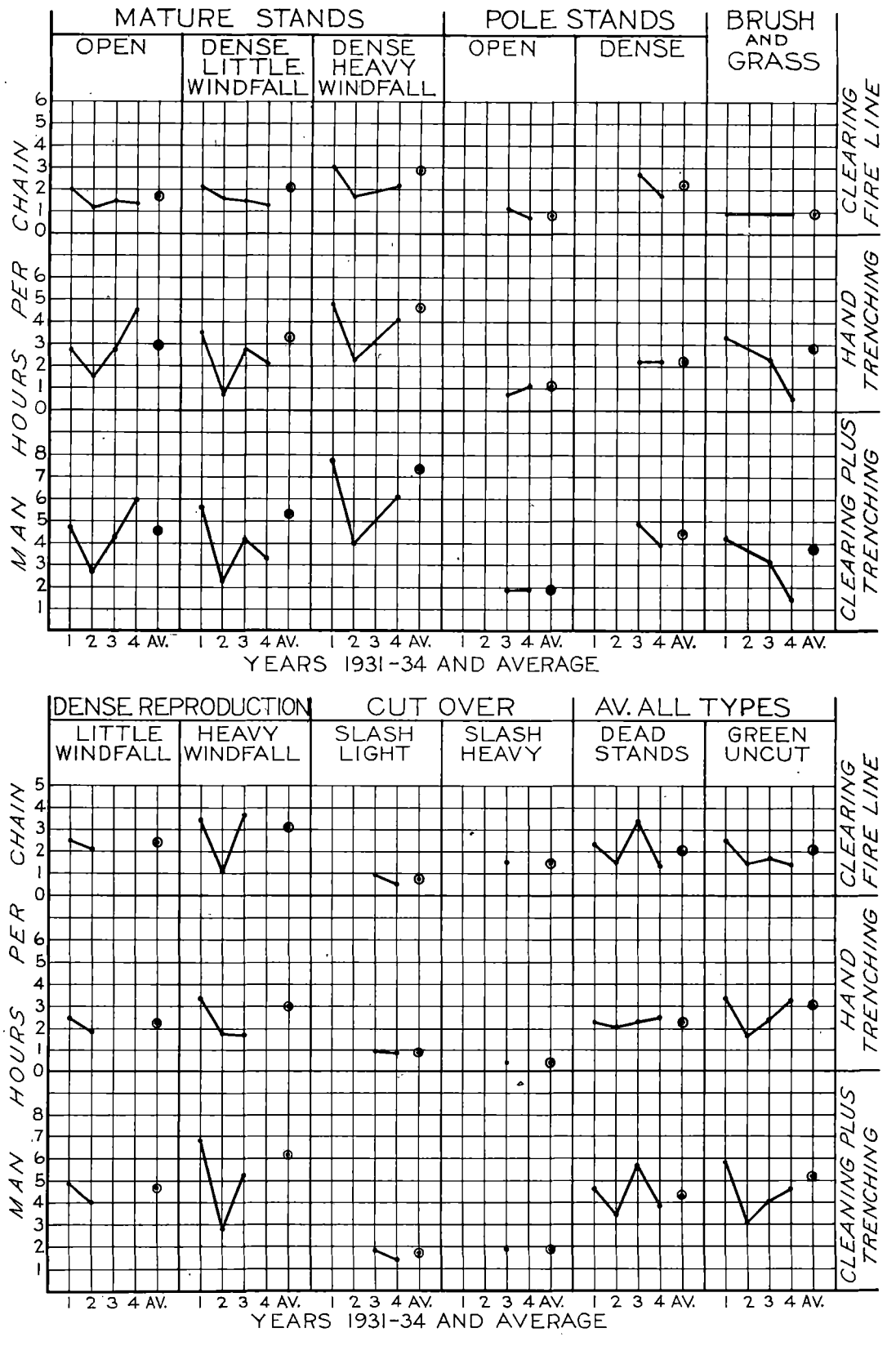

FIG.11 RATES OF WORK
ACCORDING TO AGE AND DENSITY OF STAND
MAN-HOURS USED PER CHAIN OF FIRE LINE
(BASIS, ALL SAMPLES REPORTED IN 1931-34, INC.)
R-1 WESTERN FORESTS

6 and 12-man-hour rates. Indications are that after making the greatly increased expenditures now contemplated by the Forest Service for supervision, and for training in methods of attack, organization, and supervision, the average cost per comparable fire probably will be reduced. If the burned area is more than proportionately reduced also, higher fire control expenditures of all kinds per acre could be justified on low-value areas than were indicated on page 24 for existing levels of suppression efficiency.

Number, Use, and Housing of Temporary Force

Figure 12 shows the annual comparison of number of men in the regular temporary fire-control force with the number in improvement crews available for fire duty. Except for the 20 percent reduction of regular temporary men in 1934, it will be observed that man power has increased greatly.

Figure 13 shows that the number of stations occupied by the regular temporary force, and the number provided with dwellings have increased more rapidly than the number of employees. Housing is regarded as a factor in efficiency, especially of detectors. The annual differences between graphs *A* and *B* are shown in figure 14, *A*, as percentages of the force used for overhead and service of supply. This percentage has approximated 17.5. The annual relation of graphs *B* and *C* of figure 13 are shown in figure 14, *B*, as average number of regular season employees per station. The rapid approach toward one man per station after 1927 is conspicuous.

Training in Fire Control

Training has been mentioned already in the discussion of figure 2. In figure 15 trends in the amount of training given each year, since 1921, are shown. Since these data are based on estimates and scanty records, they must be regarded as good approximations only. It will be observed that the decline in training after the 1930 peak coincided with a very large increase in untrained seasonal personnel, shown by figure 12, and a rapid and drastic reduction in year-long experienced personnel, shown by figure 2, *B*.

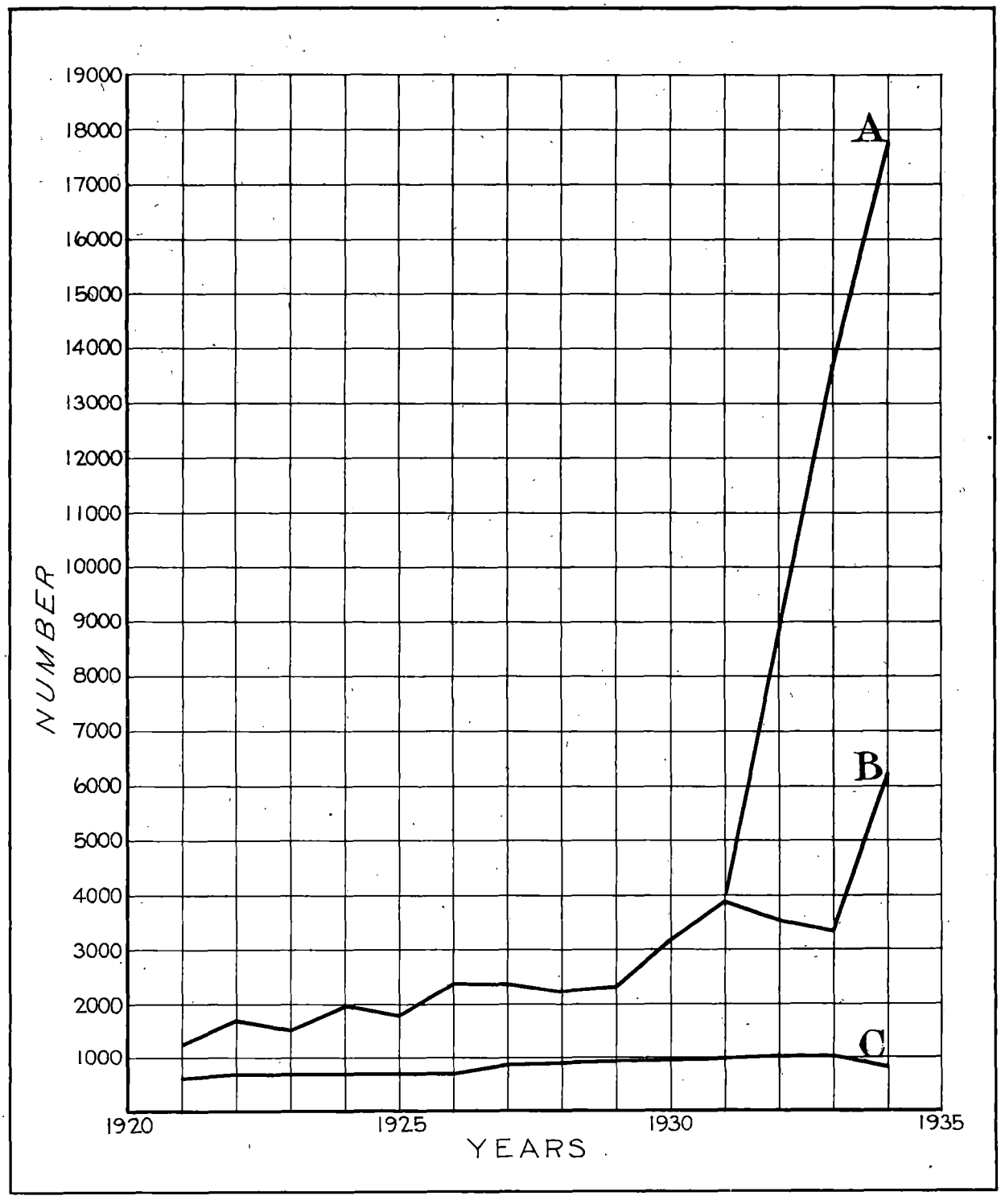

FIG. 12 NUMBER OF MEN AVAILABLE FOR FIRE DUTY

A - TOTAL INCLUDING CIVILIAN CONSERVATION CORPS
B - TOTAL EXCLUDING CIVILIAN CONSERVATION CORPS
C - REGULAR TEMPORARY FIRE-CONTROL FORCE

R-1 WESTERN FORESTS

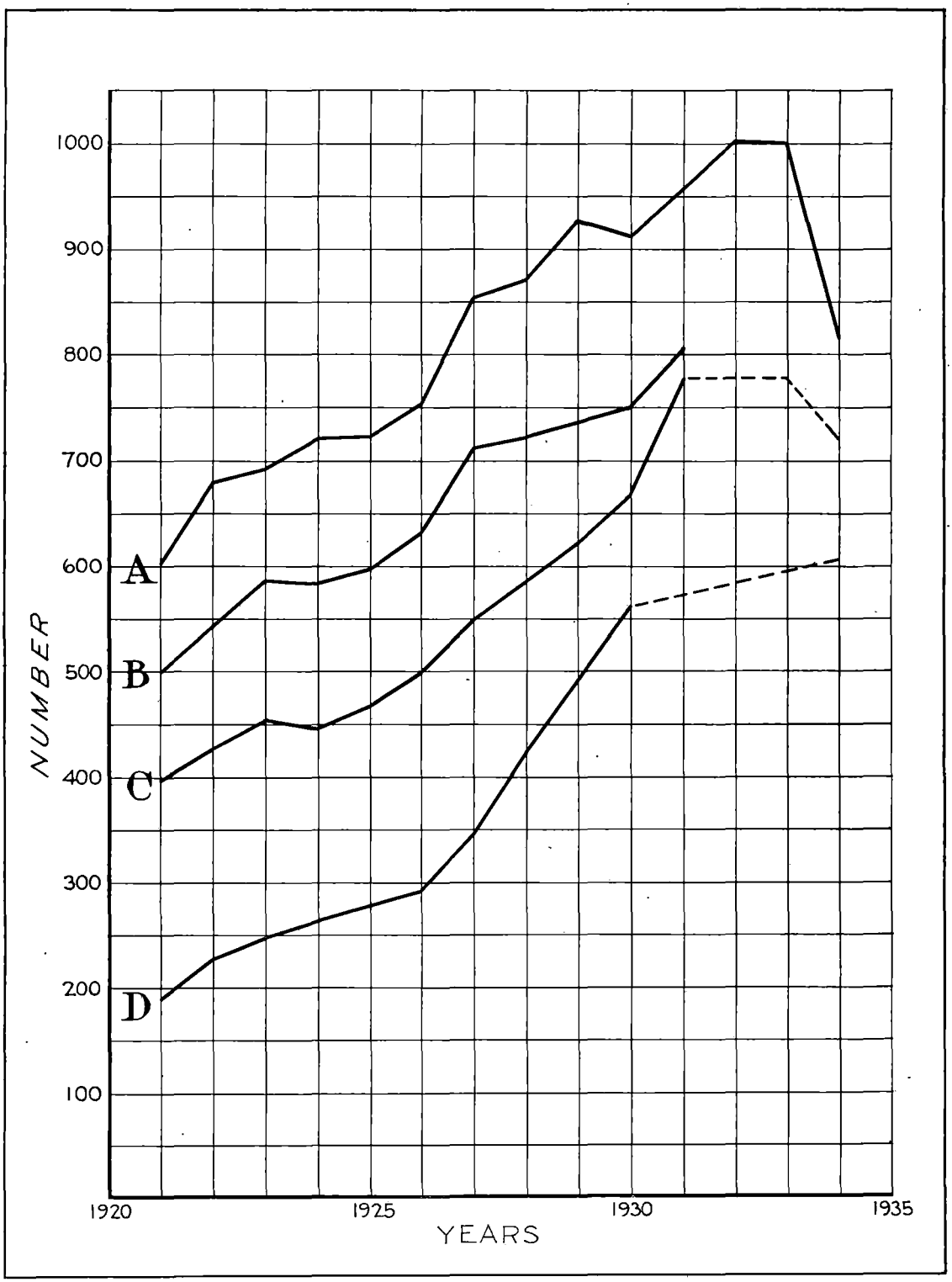

FIG. 13 MAN POWER, STATIONS, AND HOUSING OF REGULAR FIRE CONTROL FORCE

A - REGULAR TEMPORARY FORCE
B - FIREMEN OF REGULAR FORCE
C - STATIONS OCCUPIED
D - REGULAR FIREMEN STATIONS PROVIDED WITH DWELLINGS

R-1 WESTERN FORESTS

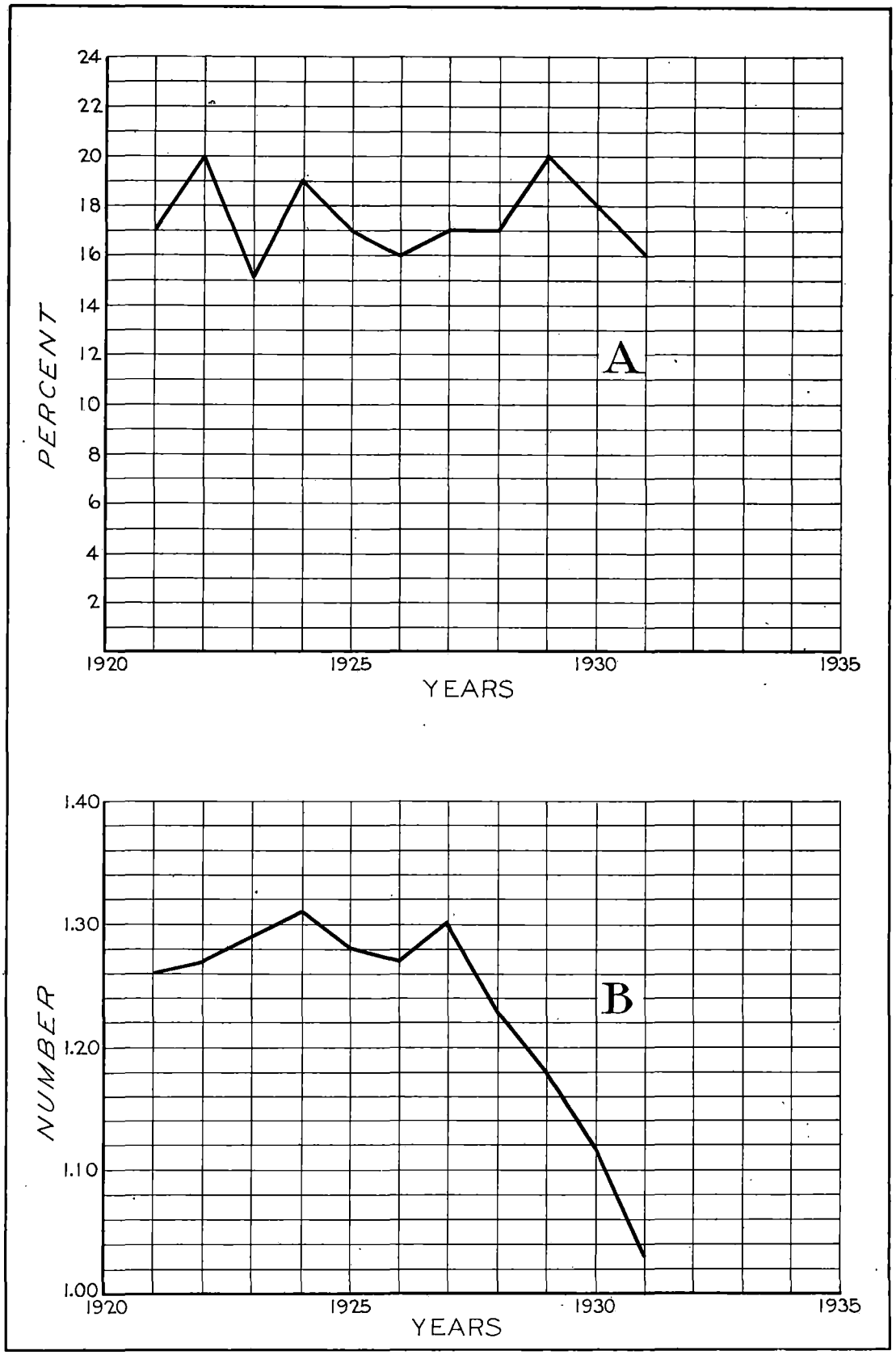

FIG.14 USES OF REGULAR TEMPORARY FORCE

A - PERCENTAGE OF FORCE USED FOR OVERHEAD AND SERVICE OF SUPPLY

B - AVERAGE NUMBER OF FIREMEN PER STATION

R-1 WESTERN FORESTS

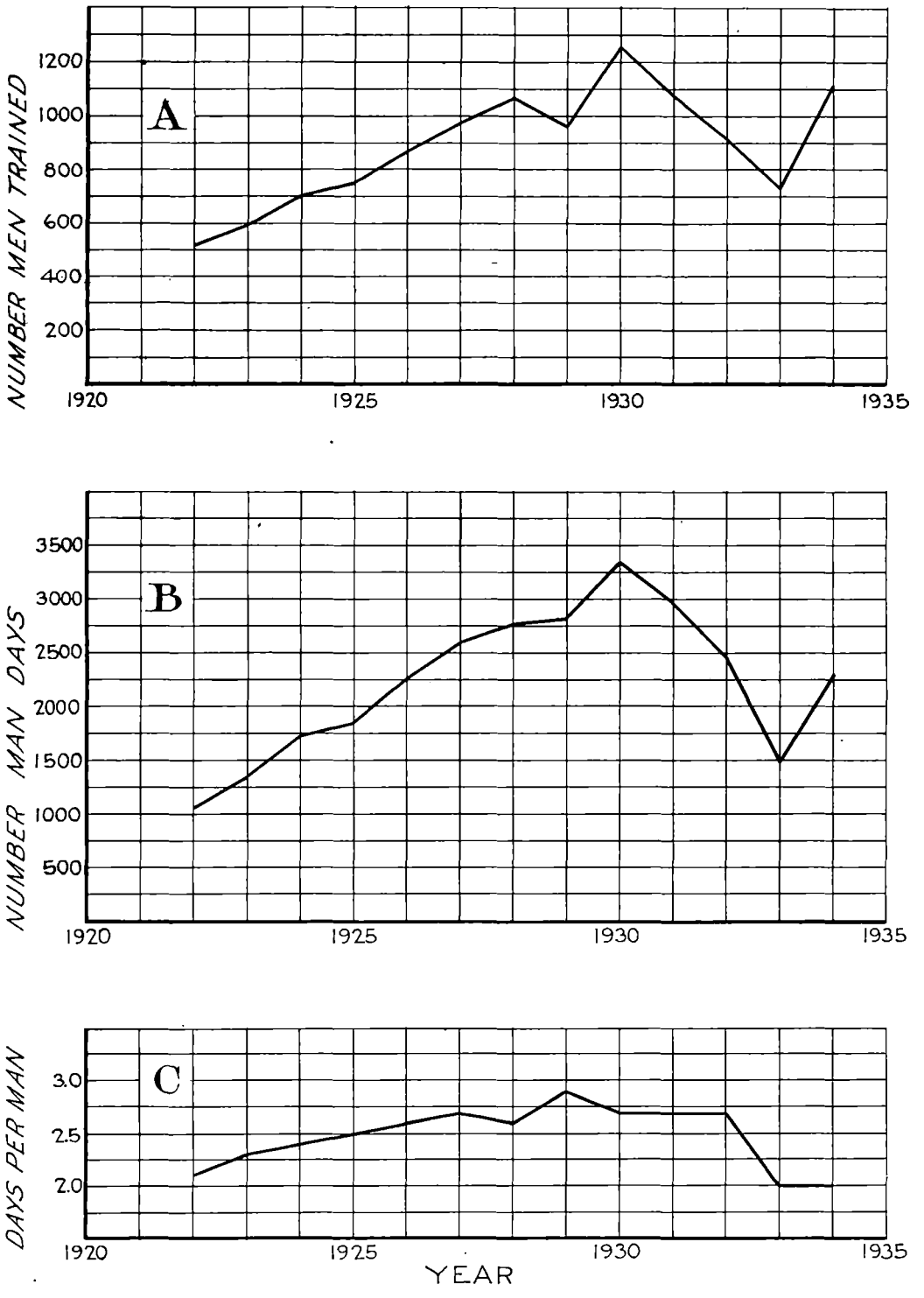

FIG.15 FIRE CONTROL TRAINING RECORD
REGION ONE WESTERN FORESTS 1922-34

A-NO. MEN GIVEN TRAINING IN FIRE CONTROL } FOR DUTIES
B-NO. MAN-DAYS TRAINING GIVEN } OF FIREMAN
C-AV. NO. DAYS TRAINING GIVEN PER MAN } FOREMAN & RANGER

FIELD WORK

MAPPING SEEN AREAS, ROAD ROUTES, AND VALUATION ZONES

The field jobs done in this planning project were as follows:

1. Fuel Mapping - The fuels on 15 million acres of national forest and cooperative lands were mapped. The detailed instructions used are given in Part II.

2. Seen-Area Mapping - Seen-area maps were made from more than 3,000 potential detection stations within the 15 million acres covered by plan work. The detailed instructions used are given in Part II. This work was done by men who had completed college courses in topographic mapping and who were further trained by J. B. Yule, in charge of maps and surveys.

3. Examinations of Road Routes - Through field examinations Regional Forester Evan Kelley decided the locations of some of the roads constructed and proposed. Other routes were proposed by forest supervisors and their staffs. Paper locations of all desirable proposed routes and additions necessary to meet travel-time standards were made in the office by road engineer H. A. Calkins. In the field he revised these locations, determined the better of alternative possibilities, and examined routes usable as connecting links between trunk routes. The procedures followed in road planning are described in Part II.

4. Mapping of Valuation Zones - Existing and potential value zones for wood products were made by logging engineer Philip Neff of the division of forest management. Relative values for recreation were worked out by Assistant Regional Forester M. H. Wolff.

MAPPING FUELS

A general knowledge of procedures followed in classifying and mapping fuels is necessary to understand the methods applied in covering them with the services of control. Disregarding timber type entirely, fuels were classified and mapped in terms of relative initial rate of spread and the resistance they offer to control. There are many precedents in engineering practice for classifying materials to be worked in such a way. Ratings were based on conditions at the end of a month of mid-summer drought.

Fuel mappers received field training in groups. Each man was provided with the written instructions given in Part II. He was required first to place each fuel examined in one of the classes of probable rate of spread, low, medium, or high, and to place outstandingly high rates in

a fourth class, extreme. Estimates of rate of spread were confined to the first 1 to 3 hours that must elapse between discovery and arrival of an attacking force. Next he was required to designate the resistance to control, using the same general terms, low, medium, high, and extreme. Maps were made on a scale of 1 inch to the mile. (For plan work, this was reduced to one-half inch to the mile.) Classes of rate of spread were shown by colors; resistance to control was shown by direction of colored lines. A section of a field map is reproduced as figure 16.

Under this procedure part of the responsibility for specifying the control action necessary is taken by the fuel mapper. While looking at the fuel in the field he has before him the best possible array of evidence. Each fuel class represents a composite condition of size, volume, arrangement, and exposure of material. Classification is based on such conditions rather than on an average indicated roughly by cover type, the basis used by Show and Kotok *(18, 19)*, because it was found that fuel characteristics within types have exerted 3 to 15 times as much influence on initial rates of spread as have forest type characteristics.

The lower picture of the frontispiece shows typical fuel conditions after logging and slash disposal in western white pine associated with western hemlock, white fir and an understory of western red cedar. Initial rate of spread is classified as Low where such fuels are exposed to the north and east, and Medium where they are exposed toward the south and west to prevailing winds and strong solar radiation. Resistance to control is Medium. If a poor job of slash disposal, or none, had been done, rate of spread would have been classified as more rapid.

The upper view of the frontispiece was obtained by looking toward the east up Benton Creek within the Priest River experimental forest. Some idea of the typical relation of topography to fire spread and a conception of the difficulty of obtaining seen area from detection points are given by this illustration. In this view are all the species commonly associated with western white pine as listed in table 3 on page 11. The fuels that govern initial rates of spread are not visible in this view and cannot be classified without examining the area; in fact, a very wide range of fuel classes was found there.

Fuel conditions in burned areas are illustrated in figure 16-A. All the trees in these views are dead. Fuels such as those shown in view 1 are common in every timber type of the region except ponderosa pine. If such fuels lie on protected north and east exposures, initial spread is classified as Medium instead of High as designated in the illustration for south and west exposures. Resistance to control is High.

Such fuels as those shown in view 2 of figure 16-A were discussed on page 15 as desirable for elimination in a fuel reduction program. The dense mass of dry grass, bark, splinters, small limbs and disintegrating trunks on the ground are 4-6 feet deep and fully exposed to sun and wind. The picture

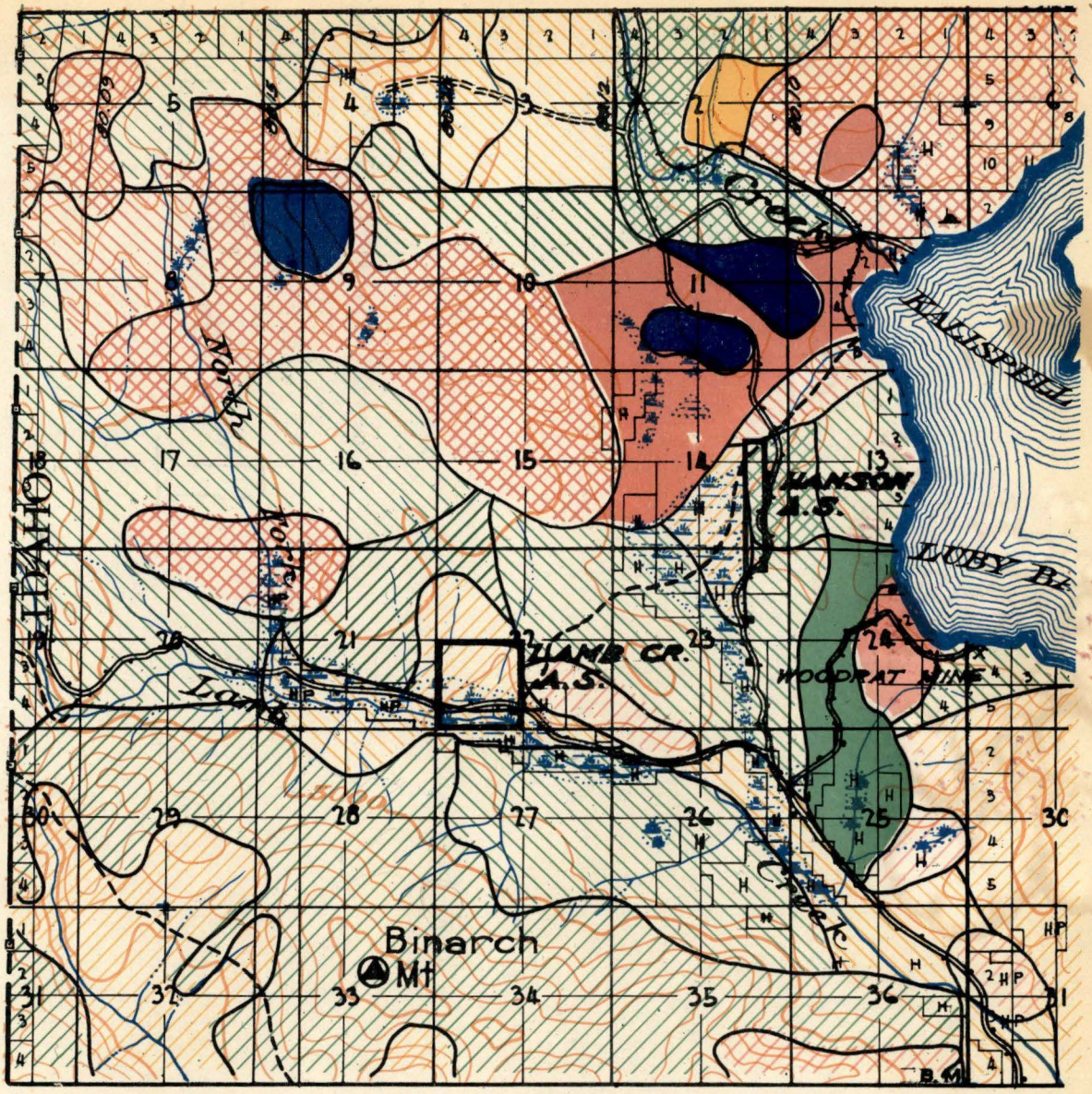

FIG. 16 FIELD FUEL MAP

(Section of Kaniksu Forest)

RATE OF SPREAD
Shown by Color of Lines

- Extreme
- High
- Medium
- Low

RESISTANCE TO CONTROL
Shown by Direction of Lines

- Solid — Extreme
- High
- Medium
- Low

Scale of 1 inch = 1 mile.
For plan work this and all other maps were reduced to scale of ½ inch = 1 mile.

1

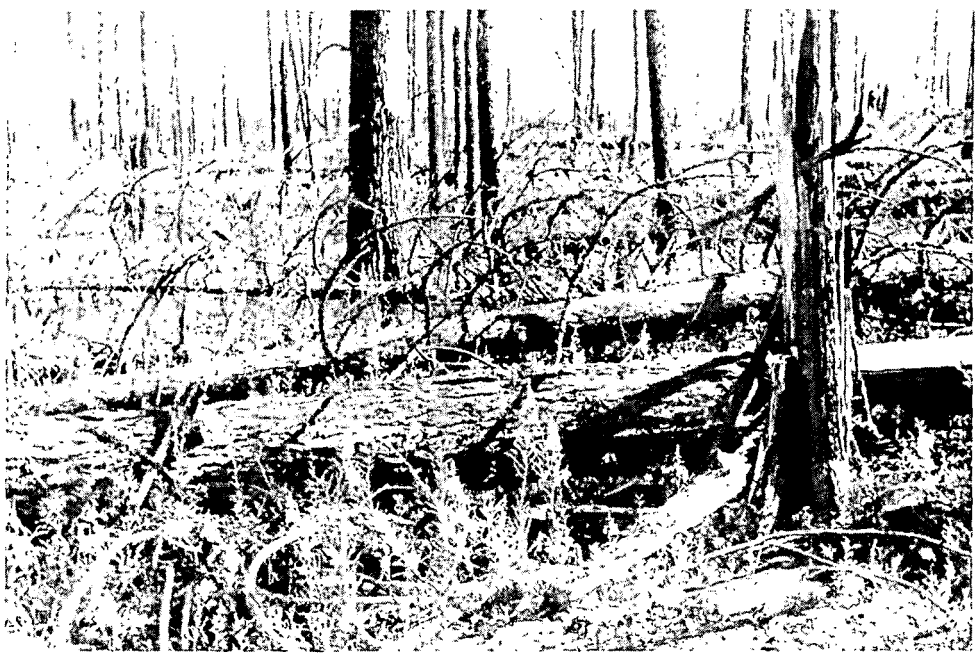

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FIG. 16-A.—FUELS IN BURNED AREAS

1. Fuel of high rate of spread and high resistance to control in the western white pine type. Such fuels are found in every timber type.

2. Fuel of high rate of spread and extreme resistance to control in the cedar, hemlock, white fir type.

was taken about 10 years after a crown fire killed the stand. Initial rate of spread is Extreme on exposed sites both near the ground and between broken broom-topped snags. Resistance to control is also Extreme.

Flashy, light fuels are illustrated in figure 16-B. In open stands of pure ponderosa pine rate of spread usually is High and resistance to control Low. This species may constitute any percentage of older stands, and brush, logging slash, and reproduction may frequently cause resistance to control to be Medium.

Cheat grass *(Bromus tectorum)* shown in view 2 was discussed on page 16 as dangerous because of its Extreme rate of spread. No other grass was allowed this rating. Its resistance to control is lower than that of any other fuel.

The few illustrations and the discussions are considered sufficient to show that fuels of the northern Rocky Mountain region vary more within any one timber type than between the averages of timber types, if indeed the average conditions of any one type could be identified. For further ratings corresponding to described conditions, the reader is referred to the 43 examples given under "Instructions to Fuel Type Mappers" in Part II.

It is not to be inferred that all the relationships between fuels, weather, and control have been determined as accurately as is desirable. Much refinement of field data and more accurate correlations between factors remain to be worked out before fire-control managers and dispatchers are provided with the degrees of detail they need.

The question whether or not fuel has been mapped accurately, that is, whether actual rates of spread correspond with classifications of predicted rates is answered to some extent by table 8. The table shows the average rates of spread of fires occurring during the 1934 season that originated in fuels mapped as high, medium, and low, under two groups of fire danger classes as indicated by danger-meter readings. 8/

Because of the limitations stated in footnotes to table 8, the rates of spread shown are not to be considered averages for their respective classes and danger ratings.

In view of the wide ranges of variation of which the averages are shown, and the small number of cases, it is remarkable that no average is found to be highly inconsistent. The half of the data first compiled gave similarly consistent averages. It is evident that in general rates of spread are being estimated consistently.

It is evident also that the ratings given by the danger meter consistently indicate differences in rates of spread to be expected, and that their general indications can be relied upon by fire-control managers.

8/ The "danger meter," developed by Gisborne (9, 10, 10a), defines seven classes of fire danger on the basis of measurements of fuel, moisture, wind, visibility, and probability of lightning storms.

Table 8.--*Average initial rates 1/ of fire spread in western forests of Region One in 1934, by fuel classification.*

Time of day	Rate of perimeter increase, under given burning conditions, in fuels 2/ of designated mapping classifications					
	Moderate (danger-meter classes 3 and 4) 3/			Severe (danger-meter classes 5, 6, and 7) 3/		
	High	Medium	Low	High	Medium	Low
	Chains per hour	Chains per hour	Chains per hour	Chains per hour	Chains per hour	Chains per hour
8:00 A. M. to 4:00 P.M.	13.1	2.4	1.3	16.4	3.3	1.1
Other	3.5	2.0	0.8	7.2	2.8	1.0
Average	8.3	2.2	1.1	11.0	3.1	1.0
	Number of cases included					
8:00 A. M. to 4:00 P. M.	28	37	13	22	37	10
Other	28	41	14	31	33	8
Combined	56	78	27	53	70	18
Total, by danger class	161			141		
Grand total	302					

1/ Data for fires that had no spread (mostly single-snag fires) were omitted from table. Data for fires reached in less than one-half hour were likewise omitted, because spreads during such short intervals are likely not to be representative.

2/ The refinement in mapping is not sufficient to insure that the classification shown is typical of the fuel in which the fires originated.

3/ The danger-meter ratings were not for specific exposures and altitudes but for whole national forests each larger than a million acres.

1

2

FIG. 16-B.—FLASHY FUELS

1. Grass on gentle slope in ponderosa pine type. Because sparse grass is heavily grazed, rate of spread is classified as Low. Resistance to control is Low.

2. Continuous cheat grass, classified as Extreme in rate of spread and Low in resistance to control.

STANDARDS ADOPTED AND THEIR BASES

In order to plan consistently and systematically it is necessary to adopt standards. After analyzing results and trends for different localities (national forests) and after summarizing them for the region, as has been done throughout this report, these data were used as the basis for formulating standards. Since the standards approved by the administration for any condition must be applied wherever and whenever that condition is found, further useful argument is restricted to questioning the standards, or interpretations of them. For each field and office procedure of major importance standards were set up.

PREPAREDNESS FOR WORST CONDITIONS

Weather, fuel, and personnel efficiency determine the speed and strength of attack needed on any fire. Preparedness for worst burning conditions requires more roads and other facilities than are needed during less difficult times. Planning determines the stations to be occupied and the man power to be placed at each under different severities of burning conditions. The term "Maximum" has been applied to a range of conditions including those that are most critical. Similarly the terms "Average" and "Minimum" represent parts of the whole range of burning conditions.

Ten years has been selected, arbitrarily, as the period for which it is hoped the present plans, with minor revisions, will satisfy requirements. In order to forecast the average annual cost of fire control and damage, it is necessary to estimate the durations of different degrees of burning severity to which preparedness and suppression costs, plus damage, will correspond. The probability of error in these estimates is very high, owing to changing seasonal conditions and lack of records. The severities of burning conditions considered, with the corresponding danger-meter classes, and the estimated duration of each in a 10-year period are as follows:

Severity of burning conditions	Danger-meter classes	Weeks of duration within 10-year period
Minimum	2	90
Average	3 and 4	86
Maximum	5, 6 and 7	24

DUAL RESPONSIBILITIES OF FIREMEN AND CREWS

It is necessary here to state that the man power planned for every location, whether one man or a crew, was assumed to perform the duties of detection as well as those of smokechasing.

MULTIPLE USES OF ROADS

Duplications of total road requirements could easily result from uncorrelated developments to satisfy separate uses, such as removal of forest products, recreation, and general administration. In planning the fire-control road system in its relation to man power, other foreseeable road requirements were given consideration so far as the authority delegated to planners permitted doing so. The evident possibilities of such correlations were far from exhausted.

VISIBILITY DISTANCE, AND SEEN AREA

In discussions here, and in general usage within the region, the term "seen area" is applied to the area that would be visible from one or more given points if the human eye could see to an infinite distance. The term "visibility distance" applies to the distance to which light, contrast, and atmospheric conditions permit an observer to see a smoke or object.

During the past 5 years the Pacific Northwest, California, and Northern Rocky Mountain Forest Experiment Stations have devoted a great deal of research effort to determining how far detectors can be expected to see the smokes created by fires of a size small enough to permit satisfactory suppression action by the first-line defense service. Unfortunately the results were not available soon enough to justify revision of the standards of allowable vision distance set up at the beginning of this plan work in 1931. Although several of the assumptions on which these standards were based have proved to be erroneous, it is believed that the defects in the standards have not caused any serious errors in the placement of detectors.

One of the purposes of the visibility-distance research was to produce a visibility meter that would enable detectors to keep fire-control managers currently informed of atmospheric conditions making it desirable to man more or fewer detection stations. Meters based on different principles have been constructed by McArdle *(12)* and Byram *(4)* at the Pacific Northwest Station and by Shallenberger and Little at the Northern Rocky Mountain Station.

The factors in visibility distance are highly complex. Professional physicists disagree on the interpretation of experimental evidence. Assuming average eyesight of the observer, the more important influences determined by investigations are prevailing atmospheric obscurity, size of smoke, and contrast with background. Under uniform conditions of atmospheric obscurity and background, the visibility distance of a standard small smoke 9/ with

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9/ In the investigations carried on by the Pacific Northwest and Northern Rocky Mountain Experiment Stations the same standardized candles were used. They produced smoke of a constant color and volume, simulating the smoke of a small forest fire.

the sun shining on it, according to McArdle *(13)*, Byram *(4)*, Foitzik *(7)*, and Buck and Fons *(3)*, is greater in the direction of the sun than away from it. Visibility distance of smoke in the shade is much less than that of smoke in the sun and, according to Shallenberger and Little 10/ and McArdle *(13)*, is less in the direction of the sun than away from it. Shallenberger and Little found the visibility distance of shaded smokes to vary (not by simply proportion) with the angle formed by two lines running from the observer to the smoke and to the sun. When the atmosphere is conspicuously clear, the visibility distances of small shaded smokes at 4:00 p.m., for observers looking in the direction of the sun and away from it are approximately 10 and 15 miles, respectively. When atmospheric obscurity is conspicuous, but not dense, these limits are reduced to 3.5 and 6.0 miles, respectively.

Topographic shadows cover large areas in early morning and late afternoon. The period of the day from 3:30 to 7:30 p.m., called evening period here, presents by far the most difficult problem in visibility distance and, hence, in the allowable spacing of detectors. Approximately 32 percent of all the fires of 1921-30 were recorded as originating in this period. Of all the fires that had to be fought during the dangerous mid-day burning period, 61 percent more of them originated during the late evening hours than in any other 4-hour period outside the mid-day period itself. The following data gives the "high lights" of a detailed study of factors for each hour of the day and night.

	5:30 to 7:30 A.M.	1:30 to 3:30 P.M.	5:30 to 7:30 P.M.
Percentage of 1921-30 fires discovered within 1 hour after estimated time of ignition....	26	61	50
Average discovery distance in miles for regularly stationed detectors.....	5.7	6.5	5.7

The increases from early morning to early afternoon and decreases thereafter show the importance of visibility distance in obtaining quick discoveries, and indicate the part that shadows and illumination plan.

Over the area that is seen from the typical detection station a larger area of shadow develops in the afternoon on the west side than on the east side. Within circles of 10-mile radius around 4 representative stations an average of 56 percent of the total seen area was found to be shaded at 5:30 p.m. on August 21, and the percentage of seen area shaded averaged 1.7 times as great in the western half-circles as in the eastern half-circles. These facts were determined by the use of profiles plotted across seen areas that had been mapped previously on 100-foot contour maps.

10/ Two manuscripts prepared but not yet published.

Other factors that effect allowable visibility distance indirectly, because they interfere with smoke rise and unobstructed views of small smokes, are height and density of tree crowns, air circulation, humidity, and character of fuel. So far as known, no measurements of these influences have been made. It was estimated that smoke would rise into view more rapidly in open stands typical of south exposures than in dense stands typical of north exposures. It was also believed that lightning-struck trees, which frequently produce smoke for a short time immediately after being struck, are more likely to hold dormant fires in the fuels at their bases for many more days on north exposures than on south exposures. For these reasons longer vision distance was allowed toward the north than toward the south in setting up standards in 1931.

For planning purposes the limits of visibility from a given observation point were represented by a figure formed by reducing and flattening the western and southern quarters of the circumference of a circle. The shortening in the west was to allow for the effect of shadows, and that on the south to allow for density of stands. Three sizes of this figure were used: One for "minimum" burning conditions, when good visibility normally prevails, a smaller one for "average" burning conditions, and a still smaller one for "maximum" burning conditions. In planning detection coverage for any one of the three degrees of burning severity, theoretically the part of the area seen from any station that lay beyond the distance limits applicable should have been disregarded. Practical considerations prevented doing this completely.

Around the four representative points studied the average acreage of seen area per mile of distance from the observer was found to be as follows: Within 4 miles, 3,500; within 6 miles, 3,093; and within 10 miles, 3,416. It is evident that between distance limits of 4 and 10 miles area seen from these four points was directly proportional to the radius, and averaged 3,336 acres per mile of radius. This figure may be regarded as a rough index to the topography characteristic of the western white pine type in north Idaho. For distances less than 4 miles this index value given would be too low. Typical topography in the western white pine type is shown by the frontispiece and by figure 16-A on page 52. An area, if entirely in view from an observer, increases in proportion to the square of the area's radius. Examinations of the seen areas of many hundreds of lookouts brings out the fact that beyond 10 miles the increase in seen area drops off abruptly except in the direction of valleys, which are usually narrow. The portion of the region not occupied by white pine type is characterized, in general, by wider valleys, to which the index given probably is not applicable. A view of such topography is given in figure 16-B on page 55.

In plan work several factors tended toward disregard of visibility-distance limits and toward the assumption that detection was effective throughout seen area. The topography of the region is such that much of

the area seen at a distance greater than 6 miles, and a considerable part of that seen at less distance, is seen from several stations; that is, the "tops of the world" are visible to all detectors. An overlap of 50 to 60 percent unavoidably exists when the largest number of stations is manned for worst burning conditions. When new coverage was added in plan work by selecting an additional station, attention was focused on making the new seen area include the greatest possible area of country not previously covered, regardless of a distance limit. Distribution of new stations was strongly influenced by the frequent absence of satisfactory detection points where stations were needed. Since every detector is also smokechaser, in locating stations some concessions were made to travel-time standards of smokechasers.

After considering the many influences that govern visibility distance and those that make an even distribution of man-power stations impossible, it is appropriate to question the desirability of working with any visibility-limit lines other than concentric circles corresponding with degrees of atmospheric obscurity. A circle is much easier to work with than any other figure. It is doubtful that selection of stations in present plan work would have been changed materially, if at all, by use of circles, and their use in the future is recommended. However, in regions of rugged mountains such as that covered by this study, where shadows are a strong factor, the visibility distance of smokes in the sun is not an acceptable standard. Fire control, being a problem of only a few percent of all fires, demands in this region that the more critical requirements of seeing small smokes in the shade and toward the sun govern to some extent the size of circle used. A decision might correctly be made in some cases that meeting this requirement would be more expensive than the damage to be expected through not meeting it.

The need for promptness of discovery depends upon severity of burning conditions; even in the absence of smoke, it is desirable to speed up discovery as burning conditions become worse. The only way to accomplish this (excluding considerations of personal efficiency) is to shorten the maximum distance from detector to smoke by manning more detection stations. The results of plan work and investigations indicate that the radii of vision-distance limits to be observed in this region when planning the locations of detectors for burning conditions of "maximum," "average," and "minimum" severity should be approximately 6, 8, and 15 miles, respectively. These standards should be used as guides rather than applied rigidly.

TRAVEL TIME AND STRENGTH OF ATTACK (TRANSPORTATION PLANNING)

For heavy and light reinforcements, the time limit within which control must be established is 10 o'clock of the forenoon following a fire's escape, which is the end of the first work period. Travel is one

of the jobs of action that must be completed within a part of the time limit. The man power to be sent is determined at the time. For initial attack the limit is also 10:00 a.m., but further standards, specifying strength of attack in relation to travel time, burning conditions, and fuels, have been set up. They are stated by tables 11 and 12, page 66.

Heavy-Reinforcement Service

Since no spot of appreciable size could be identified at which 100 firefighters or more would not at some time be needed, every spot was assumed to require their work. This is called heavy reinforcement action, or heavy second-line defense. The cities from which 100 men or more can be obtained on short notice are Spokane, Lewiston, Missoula, Butte, and Great Falls. Anaconda is included with Butte. The locations of these cities are shown by figure 1, and their populations by table 2. Control of fires by 10:00 o'clock a.m. was assumed to require delivery at fire lines and the beginning of work there by daylight. After allowing before daylight for hiring, assembling, feeding, resting, and organizing men ready for work, following the earliest probable hour of evening calls for reinforcements, a travel-time allowance of 8.5 hours was decided as applicable to heavy reinforcement action.

As shown by figure 9 on page 37 several very large areas of the region were not reachable in 1933 within the allowance of 8.5 hours. The larger portions of two of them have not been brought within this limit to date and cannot be brought within it by road construction even of the highest type. For these areas only three alternatives in planning appear to be available; establish lighted airplane routes and landing fields and provide radio beacons to overcome smoke obscurity; station large crews within a network of roads; lower the travel-time standards and hope that control will be possible within the second work period instead of the first.

The fact should be pointed out that many fires have been so large that 100 men delivered by daylight could not possibly gain control by 10:00 o'clock a.m. In fact, applying the rate of work frequently accomplished, by large crews, 1 chain of held line constructed per man per day, not more than 100 chains of controlled perimeter could be expected. Another fact to be pointed out is that 100 men, or even fewer, may be successful at some shorter distance, since a longer time before 10:00 a.m. is available. The plan work, as carried out for heavy second defense, went no further than to design a system of roads that would permit delivery of crews within 8.5 hours by automobile-bus plus walking time from the cities specified. Otherwise, for the territory lying outside the 8.5-hour time limit the same general scheme of planning was followed.

Considering the facts discussed, it should be obvious that directness of road route and high speed standards of construction are factors that compete for importance with and may be of added assistance to number and efficiency of firefighters, and they constitute a factor that can overcome handicaps in distance from man-power bases. Under certain conditions it may even cost less in total to expend more per mile along a direct route than less per mile along a devious route.

Since direct trunk routes are definitely a necessity for heavy reinforcement service, and they are not necessities for light reinforcement and first attack services, direct routes were given first consideration in transportation phases of planning. The latter were planned as connecting links and spur roads, respectively.

Light-Reinforcement Service

For severe burning conditions small mobile reinforcement crews were planned, to be stationed at strategic locations. Communities were considered man-power bases and an estimate of available man power was made for each. A wide range of action was provided by landing fields and secondary road links between trunk roads.

Travel times corresponding to fuel resistance and size of crew were worked out, and are shown by table 9. Before applying the travel times to determine the area covered by any crew, the estimated time required to assemble the men at a community center, or to assemble and transport them by airplane to a forest landing field, was subtracted. Details of planning roads and landing fields are explained in Part II.

Table 9.--*Time allowed light-reinforcement crews for assembly plus travel when burning conditions are "maximum."*

Fuel resistance to control	Time allowed for assembly plus travel for indicated number of men								
	No. of Men								
	5	8	10	16	20	25	30	40	50
	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours
Extreme				0.7	2.1	3.1	3.5	3.9	4.1
High		3.4	5.1	7.8	8.6	9.2	9.5	9.8	9.9
Medium	5.3	8.3	9.5	10.0	10.0	10.0	10.0	10.0	10.0
Low	8.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Light reinforcement action is assumed to begin in late evening, approximately 6:00 p.m. No travel times longer than 10 hours were allowed, because of the frequent early forenoon increases in aggressiveness of fires when burning conditions are severe.

The size of fire which this service is expected to control is 50 acres or less. Selection of this size was based on the data shown by figure 17, *A*. In this figure it will be observed that only 7 percent of the 2,714 fires that occurred in the very severe seasons, 1926 and 1929, were larger than 50 acres. By observing the sharp bend of the curve for sizes larger than 50 acres, it becomes obvious that an attempt everywhere to control larger fires with this form of service would entail very high expenses to maintain many more light reinforcement crews, and they would rarely be called into action. In plan work, aimed at satisfying the travel times, based on a 50-acre size, it was necessary to design an intensive system of roads in addition to placing many more crews than have been available in any locality in the past. For larger fires judgment at the time is expected to govern the action to be taken.

Initial Attack (Smokechasing Service)

Smokechasers are provided in plans with spur roads to their stations and into areas of worst fuels.

It will clarify matters to admit that a few fires become so hot within a few minutes after ignition that men cannot work directly in front of them, and that at such a spot a hundred men are no more effective than one. A few fires spread so rapidly almost from the moment of ignition that it is impossible economically to place man power close enough to overtake their advancing perimeters. These fires, if they develop into conflagrations, are part of the 2 percent considered on page 26 for which initial attack preparedness is likely to be insufficient.

Under the methods described in the following paragraphs, different allowable travel times can be determined for any rate of spread, depending upon the rate of work applied. A limiting factor, however, is whether heat from the fire will permit the man power to control fire perimeter at the rate assumed. Plans contemplate success of initial attacks during midday burning periods. On days when severe burning conditions prevail, every minute from the time of discovery to that when control is insured is fraught with the possibility of a large run. Such runs may be caused by whirlwinds, by strong direct winds (with or without the influence of slope), and by convection currents resulting from rapid production of heat, that cause fires to climb into tree crowns.

With these considerations in mind, the fire reports were analyzed for time used in successful attacks and a limit was set on the over-all elapsed time between discovery and actual control. This time limit designated "C" in the following list of factors varies with rate of spread. For initial attack to be successful the operations of discovery, report, get-away, travel, and firefighting must be completed while a fire is actively increasing in size.

The factors of initial attack are as follows:

C = over-all control time between discovery and actual control, expressed in hours.

0.25 hour = time allowed for report and get-away.

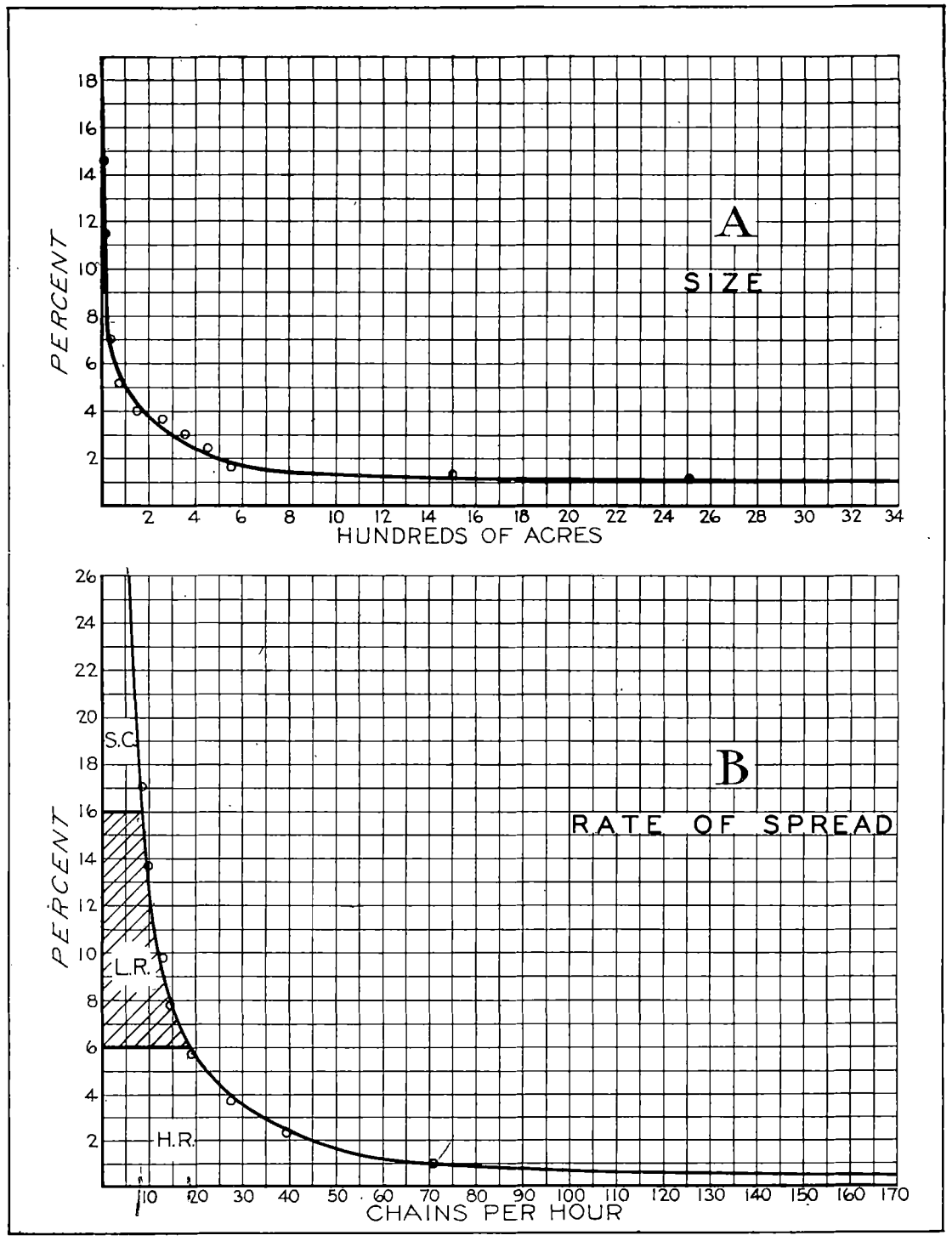
W = rate of constructing held fire line, expressed in chains per hour. Rates accomplished by using crews are not proportional to numbers of men in excess of 4.

p = average rate of perimeter increase, from discovery to time attack is begun, expressed in chains per hour.

t = travel time, the unknown and desired quantity, expressed in hours.

The interrelation of these factors is expressed by the following equation:

$$t = \frac{CW}{W + 0.5p} - 0.25 \text{ hr.}$$



H.R.=CONTROL BY HEAVY REINFORCEMENTS S.C.=CONTROL BY SMOKECHASERS
L.R.=CONTROL BY LIGHT REINFORCEMENTS

FIG. 17.—DISTRIBUTION OF FIRES AS TO SIZE AND INITIAL RATE OF SPREAD

A. Acreages of fires of two severe seasons, 1926 and 1929. Basis, total 2,714 fires. Curve shows proportion of fires that were of designated or greater size.

B. Rates of spread of fires of 10-year period 1921-30. Basis, total 8,789 fires for which rate of spread was recorded. Curve shows proportion of fires for which average rate of perimeter increase between discovery and first attack was that designated or greater.

The derivation of this formula, and considerations essential to it, are given in Part II, Pg 135. It is assumed that only half the fire perimeter needs to be worked within the over-all control time, "C," the remainder being left to be worked, under less pressure, immediately thereafter.

Table 10.--*Values used in travel-time formula for "maximum" class of burning conditions corresponding to class 5 of the Danger Meter.*

Rate of spread	C	p	Resistance to control	W 1/
	Hours	Chains per hour		Chains per man hour
Extreme	3.0	18	Extreme	0.2
High	3.5	10	High	0.8
Medium	4.0	8	Medium	2.0
Low	4.5	6	Low	3.2

1/ Applicable to each man of crews not larger than 4 men. The method of work is assumed to be hand labor, without water, with the most suitable tools. Because rates of smokechaser work according to fuel resistance could not be obtained from the records, 1,242 estimates covering a wide variety of fuel conditions were obtained from experienced men. The range of these estimates was divided into three equal parts called Low, Medium, and High resistance; the lowest rate was assigned to Extreme resistance.

Using the values of table 10 in the formula allowable, travel times were worked out and are shown in table 11. The travel time and strength of attack specifications of this table were used in plan work. Due to subsequent small revisions in table 10, the formula now gives slightly different results from those shown in table 11.

It should be kept in mind that the specifications of table 11 apply only to action in localities where class 5 is indicated by the Danger Meter. This is in the lower range of the class of burning conditions called "Maximum." Until sufficient studies have been made to determine the length of time fires can be allowed to burn before men cannot work directly on their fronts, judgment must govern the speed and strength of attack to be applied where Danger Meter ratings are in classes 6 and 7.

With fuels that require more than one man in initial attack, it was assumed in planning that the men for any fire could come partly from each of several stations located within the allowable travel time limits.

Table 11.--*Smokechaser travel time and number of men required in initial attack for indicated fuel types when burning conditions are "maximum."* 1/

Rate of spread	Requirements by class of fuel resistance to control							
	Extreme		High		Medium		Low	
	Travel time	Men	Travel time	Men	Travel time	Men	Travel time	Men
	Hours	Number	Hours	Number	Hours	Number	Hours	Number
Extreme	0.50	20	0.50	5	1.00	4	0.50 2/	3 2/
High	0.50	7	1.00	4	1.00	3	1.50	2
Medium	0.50	5	1.00	3	1.75	2	2.25	2
Low			1.50	2	2.25	2	3.00	2

1/ Burning conditions are represented by Danger Meter class 5.

2/ Cheat grass is the only fuel assigned this classification.

For burning conditions classed as "average," corresponding to Danger Meter classes 3 and 4, each of the travel allowances of table 11 was increased 50 percent and only one man was required for attack. The allowances obtained in this way are shown by table 12. The relation of approximately 1.5 to 1 was found by studying the actual travel times that have been in effect on several national forests where a high degree of success was attained under average burning conditions.

Table 12.--*Smokechaser travel times required in initial attack, for indicated fuel types, when burning conditions are "average."*

Rate of spread	Requirements by class of fuel resistance to control			
	Extreme	High	Medium	Low
	Travel time	Travel time	Travel time	Travel time
	Hours	Hours	Hours	Hours
Extreme	0.75	0.75	1.50	0.75
High	0.75	1.50	1.50	2.25
Medium	0.75	1.50	2.50	3.50
Low		2.25	3.50	4.50

The specifications shown represent steps in required action. One-man attacks have been successful in every fuel under low degrees of burning severity. As conditions become more severe it is expected that fire-control managers will apply gradations between these steps by increasing the numbers of men sent to fires and the speed of action.

Simply because a mathematical formula has been developed and used in determining travel times, one is not to infer that the specifications of tables 11 and 12 are correct. The formula only places the factors in correct relation to each other. The results are no better than the values placed in the formula.

Since each fire report shows hour of discovery and hour of, and size at, arrival of first man, on the assumption that size on discovery was insignificant it is possible to determine average initial rates of spread. The range, distribution, and trends of initial rates of spread were determined from the records of the 10-year period 1921-30. Rate of spread was measured in perimeter increase, rather than in area increase, per unit of time, because the former indicates the rate at which suppression work is increasing.

Figure 17, *B*, on page 64 shows what percentages of the 8,789 fires of the 10-year period 1921-30 spread at designated rates. The two graphs of figure 17 show that from the standpoint of both size and rate of spread the critical problem lies in the worst 7 percent of cases.

Figure 18 shows, for fires that originated in given timber and fuel types, the percentages with designated average initial rates of spread. In the analysis it was found that the percentages for single and double burns also fell within the range shown by figure 18. It is apparent in this figure that average initial rates of spread in different types of green, uncut forests free from insect epidemics and blow-downs varied somewhat in proportion to openness of stand.

Figure 19, based on the same data as figure 18, shows the division of the range of initial rates of spread that was adopted for planning purposes. Thus, for example, the classification "Extreme" was given to fuels in which it was to be expected that an initial rate of spread approximating 18 chains per hour or more would occur in 16 percent of all cases. (As figure 18 shows, cut-over areas contained one such fuel.) Similarly, 16 percent of fires in fuels classed as "High," "Medium," and "Low" would be expected to spread at the rates of 10, 8, and 6 chains per hour or more, respectively. These classified rates of spread are the ones designated "p" in table 10. Rough evidence indicates that these rates of spread correspond approximately with Danger Meter class 5. Hence, 16 percent of all fires occur in Danger Meter classes 5, 6 and 7 and many of them are expected to spread too rapidly to be caught by application of the travel times and strengths of attack specified for initial attacks in table 11. For the slowest spreading 84 percent, control by initial attack is expected.

Figure 17, *B*, shows the percentages of fires estimated to require each of the services, heavy reinforcements, light reinforcements, and initial attack. It must be recognized that the divisions are only approximate. Some rapidly spreading fires are stopped by changes in fuel, natural barriers, and rain. On the other hand, slowly spreading fires occasionally escape.

METHODS OF SELECTING MAN-POWER LOCATIONS AND ROADS

The work of determining locations for man power and roads would be relatively simple if the personnel of each of the services--detection, smokechasing, and light-reinforcement action--were independent. In designing an arrangement of smokechaser stations, frequently it was found that such a station was needed in approximately the same place where a station for detection purposes had previously been planned. If smokechasing duties were assigned to the detector, an additional man would be made available for placement elsewhere. If both duties were assigned to a given number of men, stations for each service would be closer together than they would be if only one of these duties were assigned to each station. Furthermore, it became apparent that a small crew located primarily for light-reinforcement action could perform all three duties, and that the effectiveness of crews to which the triple duty was assigned was greatest where the road system had been designed to suit this combination of duties. It was found that the total cost of men and roads necessary to satisfy all standards would be much less if the dual responsibilities of detection and attack were assigned to the man power of every station. In plan work these two responsibilities were assumed to be assigned to the man power of each station.

The dual-responsibility system is most economical even if an additional man must be assigned to each of a considerable percentage of stations for detection duty only when burning conditions are most severe. In many places absence of a detector, caused by sending the only man at a station to a fire, need not constitute a serious disruption of service. Of the total area seen from the stations manned at times of maximum burning severity, 50 to 60 percent is covered by two or more detectors. This overlapping is an unavoidable product of an endeavor not to leave more than 15 to 25 percent of any forest unseen by any detector. Before deciding that an entire station force cannot be allowed to go to fires, the planner should study the seen area left uncovered by this action, particularly as to fuels and as to frequency and causes of fires.

Assigning dual responsibility to every occupied station influences the location of stations with reference to topography. It tends to keep firemen away from high, rugged peaks and out of the bottoms of deep-cut, crooked valleys. With most of the stations located in wide valleys or at intermediate elevations, it was found that inexpensive roads could be constructed to most of them, and such roads were planned.

By providing roads where only trails existed previously, each smokechaser is enabled to cover more area within a given time, and a reduction can be made in the number of smokechasers needed within a given area. The Norcross-Grefe *(14)* method of transportation planning is based on doing this to the extent that it is most economical in the total cost of roads and smokechasers. In this region removal of a smokechaser also accomplishes the undesirable removal of a detector. Topography makes it difficult to occupy enough detection stations to satisfy seen-area coverage standards. The detection stations must be occupied regardless of road mileage provided.

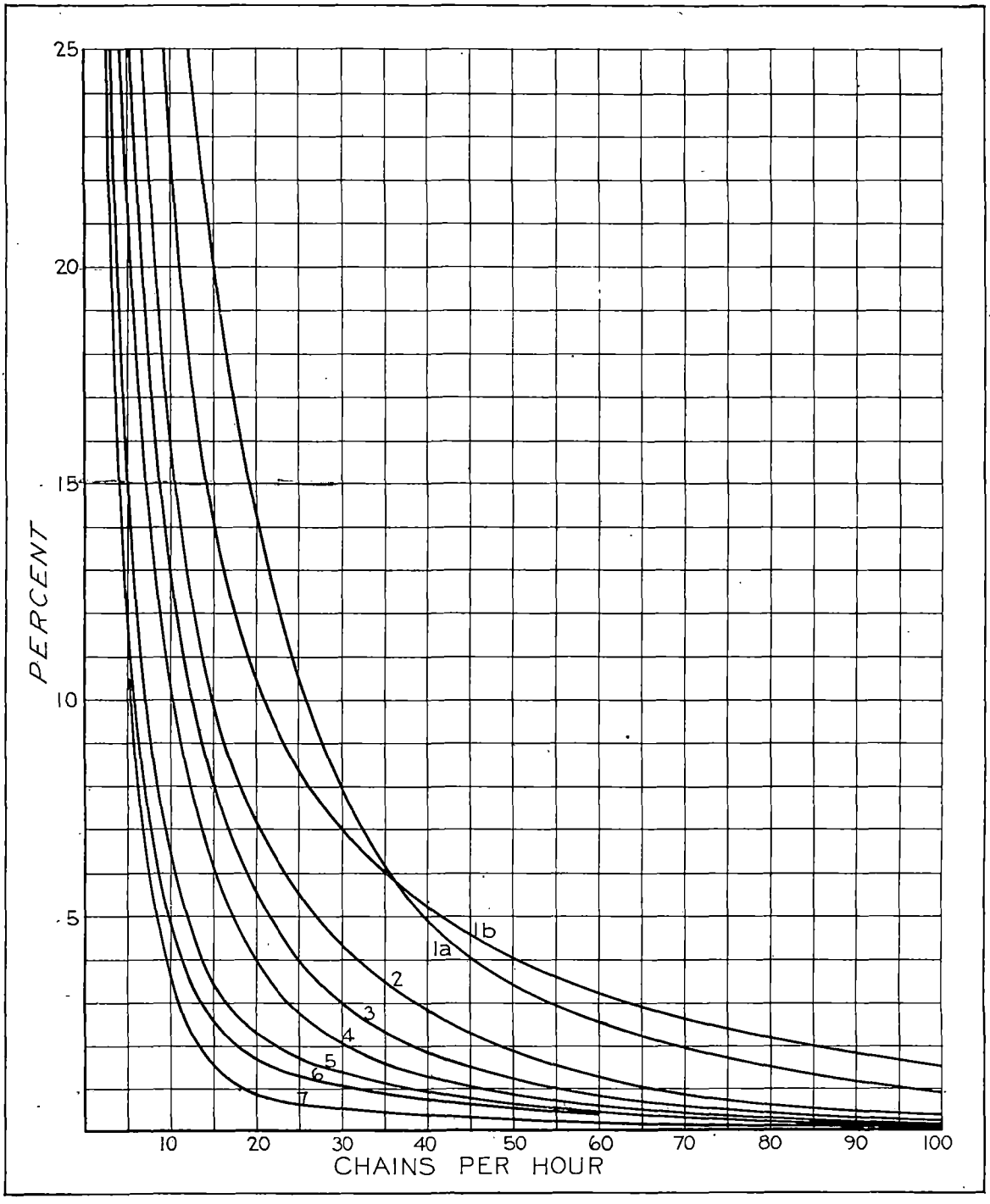


FIG. 18. INITIAL RATES OF SPREAD IN DIFFERENT TIMBER TYPES
Basis, fastest-spreading 25 percent of total 8,789 fires during 10-year period 1921-30 that were attacked within 12 hours and for which rate of spread was recorded. Curves show percentages of fires for which rates of perimeter increase between discovery and first attack were those designated or greater. With the exception of "cut over," each of the types represented is uncut green forest of pole size or larger. The types represented, with numbers of fires in each, are as follows:

1a	Cut over	1,103 fires	4	Douglas fir	215 fires	6	Subalpine	850 fires
1b	Brush-grass	710 "	4	Lodgepole pine	639 "	7	White fir-cedar	172 "
2	Ponderosa pine	996 "	5	White pine	772 "			
3	Larch-fir	673 "	5	Cedar-hemlock	110 "	7	Spruce	169 "

R-1 western forests.

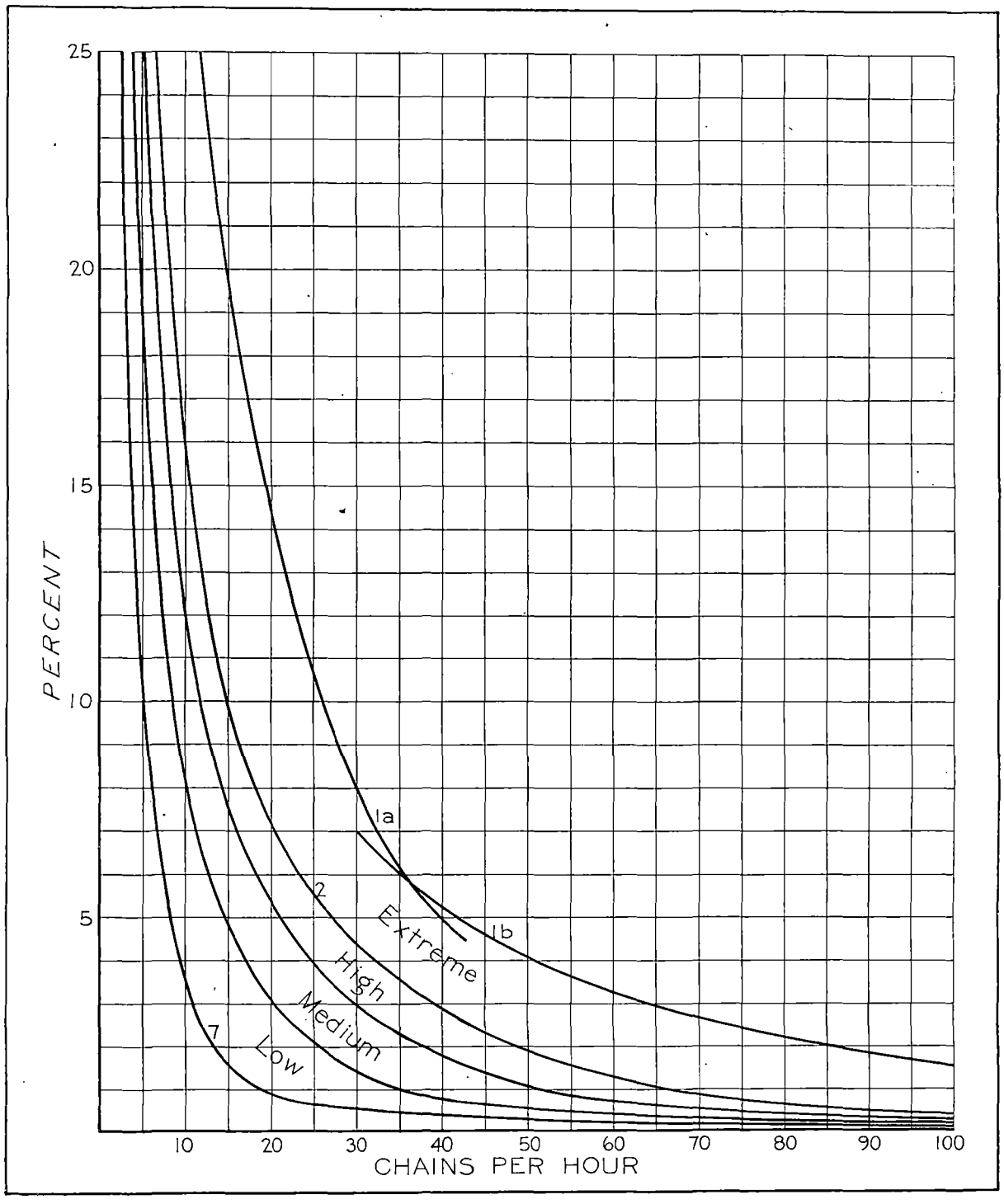


FIG. 19. INITIAL RATES OF SPREAD AS CLASSIFIED FOR PLANNING PURPOSES

Basis, total 8,789 fires of 10-year period 1921-30 that were attacked within 12 hours and for which rate of spread was recorded. Curves show percentages of fires for which average rates of perimeter increase between discovery and first attack were those designated or greater. Curves 1a, 1b, 2, and 7 are derived from Fig. 18 . Divisions of range of variation are shown in terms that were used in fuel mapping.

R-1 western forests.

Another very important consideration is that peak loads in number of lightning fires, to be expected anywhere, are likely to give more than one fire to each smokechaser. Reducing the number of smokechasers would simply aggravate the difficulty. In plan work the requirements of the road system were based on reinforcement action, except for providing firemen with connections to the system and providing other roads necessary to satisfy travel-time standards.

For many years it has been the general practice in the region to assign smokechasing duties to detectors and in periods of emergency to place on duty additional firemen charged with both responsibilities. However, a large number of smokechaser stations have been manned where detection work could not be performed. In plan work the most desirable arrangement of stations was sought with almost entire disregard of the locations of existing stations.

SILHOUETTES OF COVERAGE

Seen-area Silhouettes and Composites

A map showing the area seen from each of the 3,000 points studied as potential detection stations was copied in lacquer on a sheet of thin transparent material similar to celluloid. When such a "silhouette" was placed over a glass table-top lighted from beneath, the seen-area could be studied in relation to such conditions as fuel, frequency of occurrence and values at stake, shown on overlay maps or tracings. Assuming any set of potential stations to be occupied, by placing their seen-area silhouettes over the light in correct geographical relation to each other, as illustrated in figure 20, *A*, it was possible to see what areas were covered by the detection service, and whether they were within the vision distance limits allowed for "maximum," "average," or "minimum" burn conditions (described under the heading "Visibility Distance and Seen area," page 60). By coloring the seen area within the 6-mile limit black, that lying between 6 and 8 miles red, and that between 8 and 15 miles green, it was possible to determine the seen-area coverage in relation to allowable vision distance limits. Many different sets of silhouettes were examined over the light until the most satisfactory combination of seen areas was determined. In endeavoring to obtain the desired degree of coverage and at the same time occupy the fewest possible number of stations, attention was focused on having the small unseen areas coincide with areas containing least difficult fuels and fewest numbers of previous fires.

Smokechaser Silhouettes and Composites

With allowable travel time placed on a tracing of each of the different fuels mapped, it was possible to determine from this tracing and the map of existing roads and trails how far the smokechasers of each station could reach. Over these combined maps a silhouette of smokechaser coverage was worked out on thin transparent paper. The areas covered under travel standards for "maximum" burning conditions specified in table 11 were shown

by black pencil and additional areas reached under standards for "average" burning conditions, specified in table 12, were shown by red crayon. At long distances from a station, fuels with long travel-time allowances were covered, while those with short time allowances were uncovered, that is, were not reached. Additional coverages obtainable by constructing additional roads and trails were determined by the same procedures. Combinations of smokechaser silhouettes were studied over a glass-top table lighted from beneath in the same way that seen-area silhouettes were studied for best fit together and for danger in uncovered areas.

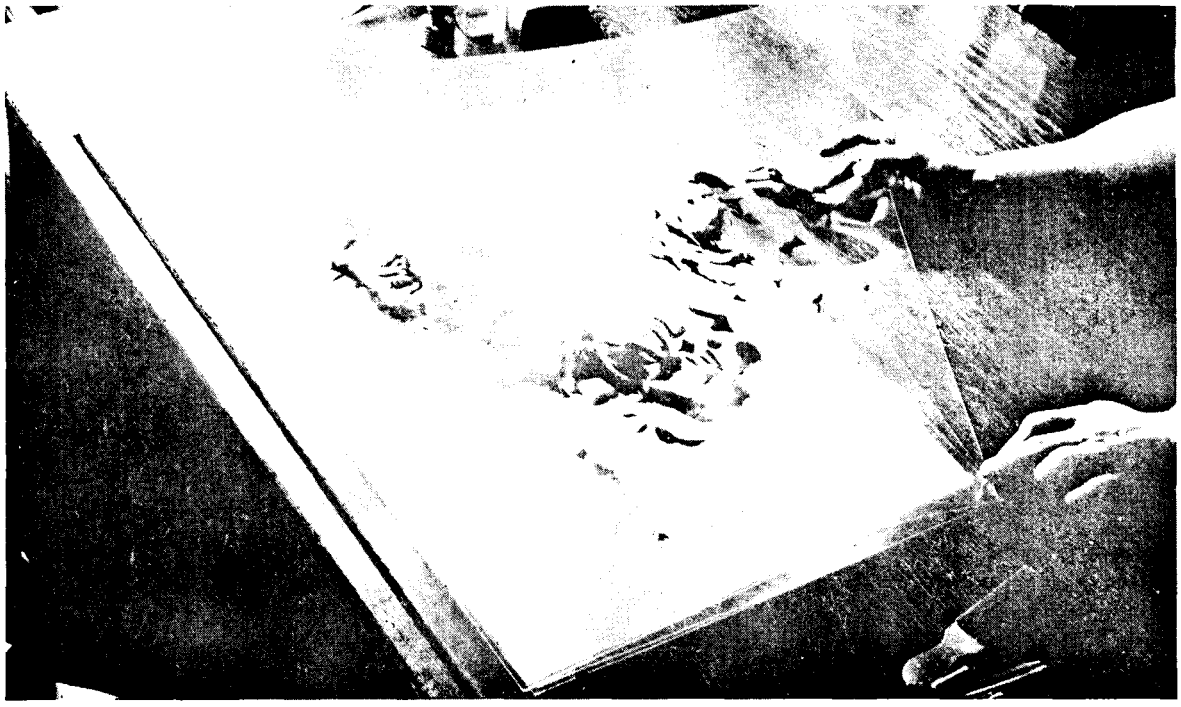
Since every detector is also a smokechaser, it was necessary to adjust determinations as to the stations most desirable for detection and those most desirable for smokechasing. The procedure found most satisfactory for this purpose was alternate use of two glass-topped tables. On one table detection coverage was built up; and on the other, smokechasing coverage. Detection coverage was given preference, because it was found that the number of places from which detection coverage could be obtained was much more limited than the number desirable to occupy for smokechasing purposes.

Whenever a seen-area silhouette was inserted in the detection composite being built up, the smokechasing silhouette for the same station was inserted in the smokechasing composite on the other table. In this way the stations to be occupied were determined and tracings (composite silhouettes) of the areas covered by each of the services were obtained. The smokechasing coverage added by occupying any particular selected station might permissibly be small if the detection coverage added was large, and vice versa. The value of a station was determined by the sum of new coverages obtained in each service and by the degree of danger existing in these new coverages. ("New coverage" means the area added after certain stations have been selected. Obviously, new coverage depends upon the order in which stations are selected.)

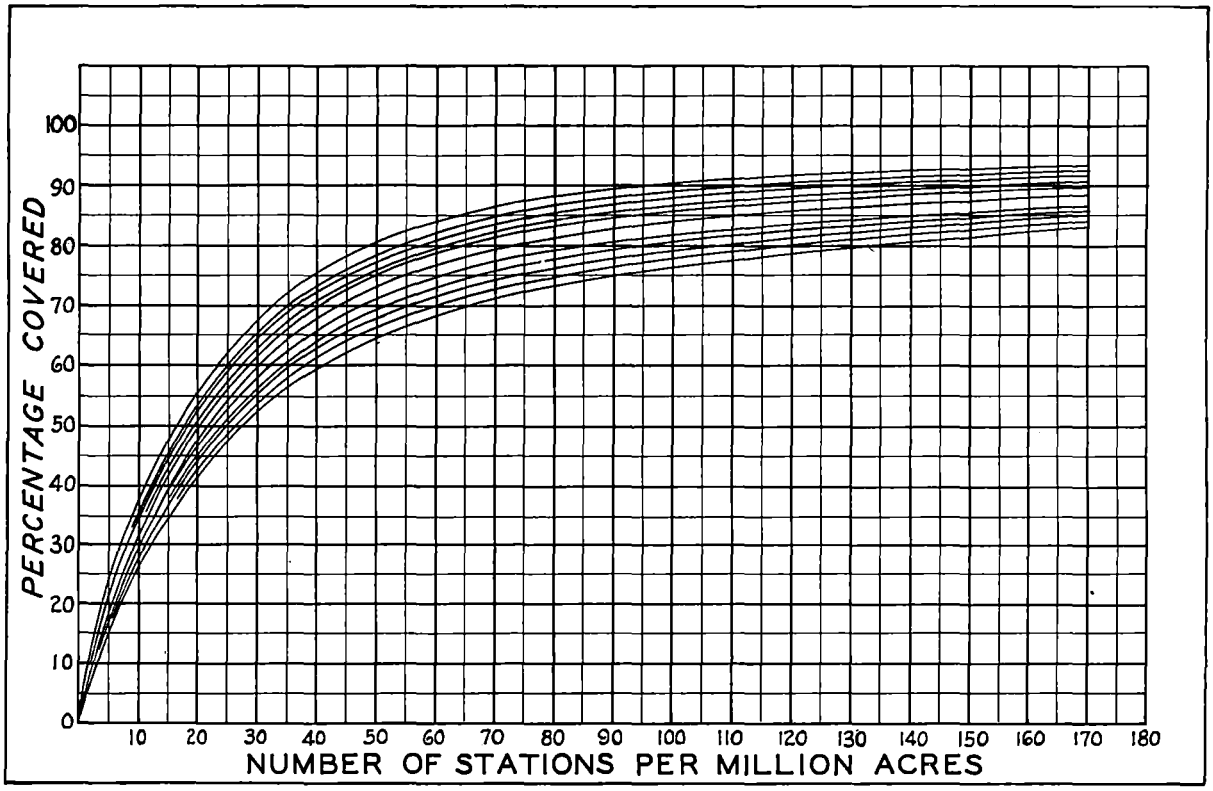
Attempts to make mathematical ratings of new coverages to govern priority of selections was abandoned when it was found that equally accurate and more practical selections could be made in much less time by visual methods. It was found that when the detection and smokechasing coverages have each been built up to approximately 60 percent, the uncovered remainder usually consists of small disconnected patches and irregular narrow strips. In them it is desirable to evaluate carefully any new coverage gained, for the reason that the addition is frequently so small as to be economically questionable.

Reinforcement Coverage Composites

Coverage composites for the services of light and heavy reinforcements were worked out in conjunction with road plans. For light reinforcement service the areas were shown that could be reached within the travel times specified by table 9 for different numbers of men, available in communities or planned for placement in camps. For heavy reinforcement service, the areas that could be reached in 8.5 hours' travel from Spokane, Lewiston, Missoula, Butte, and Great Falls were shown. In addition this composite showed the area that could be reached in 12.5 hours' travel time, and the area that lay within 4 hours' walking distance from the nearest road, landing field, or man-power base. The coverages existing and planned in the different forest units of the region are shown by table 13.



A



B

FIG. 20.--DETECTION COVERAGE

A. Method of sorting seen-area silhouettes for desirability and best fit together into composites.

B. Percentage of coverage obtained according to number of stations manned per million acres.

Table 13.--*Coverages made possible by roads, trails, and landing fields in western forests of Region One*

Reinforcement services and conditions		Forests 1/ and percentage covered												
		1	2	3	4	5	6	7	8	9	10	11	12	W
HEAVY REINFORCEMENTS														
Reached by 6:00 a.m. 2/ with not over 4-hour walk	In 1935	44	81	98	39	18	42	91	71	42	83	28	72	57
	Planned	50	96	100	86	27	50	97	94	55	94	51	90	73
Reached by 6:00 a.m., no walking limit	In 1935	44	85	98	40	19	42	91	82	42	84	28	72	61
	Planned	51	96	100	86	27	50	97	96	55	94	51	91	75
Within 4-hour walk, no arrival limit	In 1935	81	87	100	58	33	78	95	73	76	88	33	78	73
	Planned	96	97	100	100	61	94	100	96	96	99	92	100	95
Reached by 10:00 a.m., no walking limit	In 1935	90	100	100	74	46	93	99	97	78	99	37	93	84
	Planned	97	100	100	100	65	99	100	100	95	100	91	100	96
LIGHT REINFORCEMENTS														
Within 4-hour walk	In 1935	83	86	98	55	40	89	84	73	67	97	34	61	72
	Planned	99	98	98	100	67	99	96	97	92	99	93	99	93
No walking limit	In 1935	91	98	98	65	64	96	94	86	76	98	38	79	82
	Planned	99	100	98	100	88	99	98	99	94	99	96	99	97

1/ Each forest is given the number shown below.

1. Blackfeet
2. Cabinet
3. Coeur d'Alene
4. Clearwater
5. Flathead
6. Kootenai
7. Kaniksu
8. Lolo
9. Nezperce
10. Pend Oreille
11. Selway
12. St. Joe (Main)

W. Western forests as a group.

2/ Arrival at the fire by 6:00 o'clock a.m. is estimated to be the same as using 8.5 hours for travel out of the total time required after hiring, assembling, feeding, and resting a crew of 100 or more men.

For heavy and light reinforcement services table 13 shows the percentage of area reached in 1935 and that planned on each of the forests included in plan work and under each of the conditions of arrival time and walking that are important considerations in fatigue and control within the first work period. Large variations in existing and planned coverages will be observed. These variations are caused largely by exclusion of roads from wilderness areas, by variations in distance from man-power bases and by the impossibility of reaching within 8.5 hours the larger areas shown in figure 9 of page 37. Mileages and costs of construction and maintenance of existing and proposed roads were worked out and the proportions chargeable to fire control were estimated. Annual costs were determined by amortizing investments on a 50-year-life basis.

RELATIVE DANGER RATINGS

After detection coverage has been built up (by the methods of selection just described) to about 60 percent, each new station adds a relatively small area to the total already covered. The same condition is found in building up coverages in the services of smokechasing, light reinforcements and heavy reinforcements. In order to justify further additions to each coverage the planner must evaluate what is gained, and continually he must determine whether an addition is more valuable in one place than in another. In the areas under consideration different numbers of fires per unit of area must be expected, fuels are different, and the values at stake vary greatly. The decision as to relative danger cannot be based on any one of these factors alone, but must be based on an integration of them. A method of integration was developed and a map was made showing intensity of total danger existing in different areas. Additions in coverage were evaluated by multiplying the acreage added by the intensity of danger within the area. The product expressed as so many danger points showed the relative merits of adding a station (or road) in one place or another, no matter how far separated the proposed stations (or roads) might be.

In working out these ratings it was recognized that the danger from one fire is the sum of probable expense plus probable damage. In total, the danger is expense plus damage multiplied by the number of times it will happen. Expressed mathematically

(Expense + Damage per fire) x frequency of Occurrence = Danger

Damage is enclosed within a fire-perimeter along which expense is incurred. Rate of fire spread and resistance to control, shown on fuel maps, determine the rate at which both damage and expense will accumulate. After arbitrarily assuming a length of burning time, the fuel maps provide the basis for determining probable expenses according to the resulting size of fire and resistance of fuel to control. A map showing probable damage per acre was made by methods explained on page 77.

In working out these ratings fires were assumed to spread 4 hours (the average duration of uncontrolled daily spreads) at each of the rates shown for Extreme, High, Medium, and Low in table 10. For each of the fire sizes thus obtained the man hours of firefighting time were determined

for resistances to control Extreme, High, Medium, and Low. In this way the expense of control for each size of fire was expressed in man hours.

Expense is not confined to fire-line work, and overhead, transportation, equipment, and presuppression costs must be included in order to obtain the complete expense to add to damage. Dividing all costs of the period 1921-30, including Regional Office overhead, by the number of man hours reported on actual firefighting work, the cost per man hour was found. That cost was used in working out the probable expense of control.

In spite of the apparent sources of error involved in making a fire-danger map by this method, the classifications worked out seem to correspond satisfactorily with opinions of different groups of well-informed men regarding the relative importance of fire control on different areas. Substitution of judgment integrations of these factors for the more laborious method used is not desirable because judgments have failed to be consistent and have failed to refine estimates to specific small areas. Whatever opinion is held regarding the value of danger ratings integrated by this or any other method, it must be admitted that each of the factors set forth becomes an important consideration in some place and that no one factor can be selected as the sole consideration in determining the degree of fire-control organization needed. It must also be admitted that opinions held by administrative officers regarding values have governed the distribution of presuppression funds. The attempt has been made here to recognize values systematically. Nothing more is claimed for the danger formula than that it states the natural relation of factors to each other. Until these factors can be evaluated accurately, it appears more correct to estimate them as accurately as possible than to avoid such estimates.

The numbers of danger points that would be covered by use of proposed roads, trails, detectors, and smokechasers have been used as priority ratings of the sequence in which they should be established.

Fuels Worse Than Average

In building up coverages of detection and smokechasing, fuel alone was allowed to govern the selection of stations up to the point where uncovered areas became ragged. This procedure was found not to conflict with the advocated use of total danger ratings. A tracing of areas where fuels were worse than average was used continually as an overlay on coverage composites being built up. The class of fuel considered average, that with medium rate of spread and medium resistance to control, was thrown with all fuels given longer smokechaser travel time allowances. The fuels classed as worse than average were found to cover 25 to 35 percent of the areas of different forests.

Ten-Year Occurrence Map

Another tracing used as an overlay showed the number of fires per thousand acres that should be expected. In making this, a square of 1,000-acre size was used over a tracing of all fires that occurred in 10 consecutive years, and whatever number of fires fell within it was written on the tracing at that spot. After the tracing was completed for a forest, the entire area was subdivided into parts that appeared to be approximately uniform, and each part was labelled with the nearest whole number of fires per thousand acres estimated reasonable to expect there in the next 10 years. No area received a rating less than 1. It should be noted that any one of these final numbers is not the average number of fires that occurred per thousand acres.

In this work, fires caused by railroads and brush burning were excluded from consideration because recent trends indicate that laws and fire-prevention efforts will make their influences insignificant. Areas where incendiary fires were conspicuous were identified and eliminated from general consideration. After the selection of stations was completed, these areas were restudied, and if coverages were insufficient, added stations were determined for occupancy as long as the incendiary cause continues to be an important consideration. Fires caused by lumbering were excluded because the area subject to them moves with logging. However, from the standpoint of fuels, areas logged or about to be logged were given special consideration. It was found that fires caused by smokers, campers, and fishermen were more numerous in the vicinity of logging operations. This was attributed to the fact that logging roads make areas more easily accessible to recreationists. Allowances were made for changing tendencies in these causes also. The areas, shown by figure 5 on page 31, where peak daily loads of lightning fires have been repeated were given special consideration.

A valuable use of the 10-year occurrence tracing was in determining the seasonal period of occupancy for each station. This tracing showed the origin spot of every fire by a small circle colored to show the size class of fire that developed. Within the circle a letter showed the cause, one number showed the year and another the month, and the color of the enclosed figures showed 10-day period of occurrence. By studying this tracing it was possible to shorten the previous period of occupancy of many stations and use the savings for more men or stations when and where conditions were more critical.

Damage Valuations

The Region One Division of Forest Management worked out, by extensive field work, rough appraisals of stumpage value. Based on these appraisals, average fire-damage valuations per acre were estimated. Site quality was evaluated regardless of whether mature timber was present.

In appraising the values of stands it is necessary to recognize that protection from fire is a factor of value. With a low degree of protection a given stumpage is worth less than where a high degree of protection is paid for by some agency other that the purchaser.

If values at stake are used as a factor in necessary strength of fire-control organization and placement of man power, the planner must recognize that high-value stands now mature will within a few years be replaced by reproduction. If a station remained in use throughout a rotation, the values covered by that station would vary from zero to that at maturity. For planning purposes one-half of the appraised value per acre of a mature stand was used as the average value. No values of salvage after fires were allowed except in the ponderosa pine type.

The Region One Division of Lands worked out, with forest supervisors, rough appraisals of probable fire damage to recreation. Class values were worked out and identified on maps. These values must be regarded as relative and tentative only. They constitute a first attempt to compare recreation values with wood-products values. The values assigned ranged from $0.50 to $350.00 per acre, the latter occurring in and adjacent to groups of summer homes.

Much argument and little agreement resulted from attempting to estimate fire-damage values on the large forest areas of the region that are too inaccessible, and occupied by too scrubby stands, to have wood-products values and that have the lowest potential recreation value. Estimates solicited ranged from $0.10 to $2.00 per acre, averaging about $0.50. Since all values were rounded off to the nearest dollar and recreation had already been assigned a value of $0.50, these areas automatically fell into the $1.00 per acre class and this value was the lowest one used.

COVERAGE ACCORDING TO BURNING CONDITIONS

In making plans for "Average" burning conditions longer travel times for smokechasers and longer vision distances for detectors were allowed than in making plans for the most severe class of burning conditions, called "Maximum." For "Minimum" burning conditions, still longer vision distances were allowed. Coverages were worked out for each of these services under each class of burning severity. For the services of light reinforcements and heavy reinforcements coverages were worked out only for "Maximum" burning severity, using the specifications described under "Travel Time and Strength of Attack," page 61. Each of the coverages mentioned that involved travel was worked out using existing roads and trails and again assuming the existence of proposed roads and trails. More exactly, proposed manpower placements and proposed roads and trails were worked out in different combinations until a decision as to the best combinations was reached.

When the general burning conditions over a tract of 1 million or more acres are "Minimum," certain spots more exposed to drying influences than others develop "Average" or even "Maximum" conditions. This phenomenon is frequently exhibited early in the season at lower altitudes on south and west exposures. Mature cheat grass is one fuel in which a high rate of spread must be expected on any fair day regardless of conditions prevailing over the general locality. It is assumed that whatever plan, or part of plan, applies to the specific burning conditions in any small area will be put into effect.

COVERAGE IN RELATION TO NUMBER OF STATIONS MANNED

DETECTION COVERAGE

The area seen from the first point selected for occupancy is usually larger than that seen from any point selected later. Furthermore, the entire coverage is new and free from overlap. After 50 percent of the total area has been covered, overlap begins to accumulate rapidly. After 80 percent coverage is reached, most of the area seen from each new point selected is overlap, and the 20 percent of total area still not covered consists of small, scattered patches. It would require the occupancy of about 500 points per million acres to obtain 100 percent coverage. As is shown by figure 20, *B*, page 73, one-tenth of this number, 50, would cover 65 to 80 percent, varying principally with topography and the amount of patrol detection required around each point. Each curve of figure 20, *B*, shows approximately the percentage of area that would be covered in a particular kind of northern Rocky Mountain topography by occupying any number of stations per million acres. No limit is placed on vision distance. Patrols requiring more than 15 minutes from each main station have been eliminated from consideration.

Detection patrol, as used, means travel from point to point with observations of 15 minutes required at each point where a stop is made. No detection is credited from an observer in a moving automobile unless someone else is driving it.

Obviously, one way to obtain a high degree of detection coverage per station is to require long patrols from each one. One man could effect a 90 percent coverage of an enormous area if he were allowed a week in which to do it. Although it verges on the ridiculous, that is exactly the form of detection practiced in many of the more remote localities of this region as late as 1915. In the plan work described here, where roads run along ridge tops and between good observation points in valleys, patrols and facilities for frequent communication have been planned. For "Average" burning conditions longer patrols have been planned than for "Maximum" burning conditions.

Neither fire-control managers nor planners should fail to recognize that even the most efficient of detectors do not and could not observe continuously. One may as well believe in Santa Claus as to presume that detectors observe for 24 hours each day, the regular period of duty assigned to each detector in this region. Assuming that 10 minutes is a reasonable estimate of the relief time each detector should use between intensive observations of his seen area, he may be able to effect more detection per dollar of expense by using this 10 minutes moving to another point than by walking around within the space of his observatory. A continuation of planning now being carried on is determination of lengths and routes of patrols (station-to-station detection) to be used.

The most efficient detection by a given number of men is assumed to be that which effects the largest number of hours of coverage, weighted according to danger existing in the area covered, that is, according to the integrated danger in fuel conditions, frequency of occurrence, and values at stake. Values were regarded as determining in part the number of detectors (and other factors of strength) allowed per unit of area. A detailed study to determine for selected areas the basic principles upon which to plan the most efficient routing and scheduling of detection patrols is now needed.

A statement of the percentage of area covered by detection in any locality is not complete and hence cannot be used as a basis for comparison with coverages in other localities until the extent of patrolling and the vision distance limit used are stated.

SMOKECHASING AND GRADATION INTO LIGHT REINFORCEMENT COVERAGE

In each of the coverages obtained by smokechasers, light reinforcements, and heavy reinforcements, the first stations or roads selected effect much greater coverage per station or mile than any of those selected thereafter. Any one of the curves of figure 21 shows for smokechasing coverage the rapidly diminishing returns per station after 30 stations per million acres have been selected. This figure shows the wide range of variation in coverage delivered by any particular number of stations per million acres. The variation is caused chiefly by mileage of roads per unit of area and the proportion of road mileage that can be traveled at high speed. Each curve of figure 21, *A*, or 21, *B*, applies to a locality in which a uniform intensity of road mileage exists. Coverage curves for low speed areas take the shape of the lower ones while curves for high speed areas have the shape of the upper ones in each chart.

In comparing figures 21, *A*, and 21, *B*, it will be observed that smokechaser stations must be much closer together when burning conditions are worst (in the Maximum class) than when they are Average. The comparative numbers of stations required to reach 80 percent of an area are shown by the upper curves in each chart to be 60 and 30 stations per million acres respectively. The conditions under which these coverages are possible are found in such areas as those of the Cabinet and Kaniksu forests, where the highest speeds are possible on Federal and State trunk highways and where many tributary roads (some of them permitting relatively high speeds) make adjacent areas highly accessible.

The lowest curve of chart *B* shows that in localities where no roads exist, as in parts of the Selway and Flathead forests, to reach 80 percent of the area under travel times applicable to Average burning conditions, 145 stations per million acres are necessary. Under the shorter travel times applicable to worst (Maximum class) burning

conditions, the lowest curve of chart *A* shows that more than 200 stations per million acres are necessary. Considering that even in recent years such areas have not been provided with more than 35 to 50 stations of all kinds (including crews) per million acres, the very high cost and the administrative difficulties of meeting these travel-time and man-power requirements with trained men and without roads become evident.

Although these travel times are short enough to present a difficult problem in first attack, they still fall short of meeting the needs of about 10 percent of all fires. It should be recalled that on pages 66 and 67 these travel times were shown to correspond with no greater severity of burning conditions than indicated by class 5 of the Danger Meter. To satisfy the still more exacting requirements of Danger Meter classes 6 and 7 either of two courses may be followed. Still shorter travel times can be worked out for each fuel, using still greater numbers of men, thus providing even more stations per million acres, or, dependence can be placed on mobile light reinforcement crews. The decision, which was made to follow the latter course, carries with it the obligation to plan for and establish these light reinforcement crews and the roads, trails, landing fields, and other facilities necessary to make them effective. In the last two lines of table 13 on page 74 are shown the existing and planned degrees of coverage by the light reinforcement service.

For the benefit of those now engaged in plan work in other regions it should be pointed out that evidence of the need for a light reinforcement service in this region is shown in the following places in this report, figure 2 on page 23, table 6 on page 25, figure 9 on page 37, figure 17 on page 64, and the discussion on page 67 as related to figure 18 on page 69 and figure 19 on page 70. Thus through analyses the evidence accumulated, but not until sufficient plan work had been done to construct the curves shown by figures 21, *A*, and 21, *B*, was the evidence conclusive. The gradation from smokechaser action alone into it supported by light reinforcements probably involves the most difficult phase of successful fire control and hence also the most difficult phase of plan work.

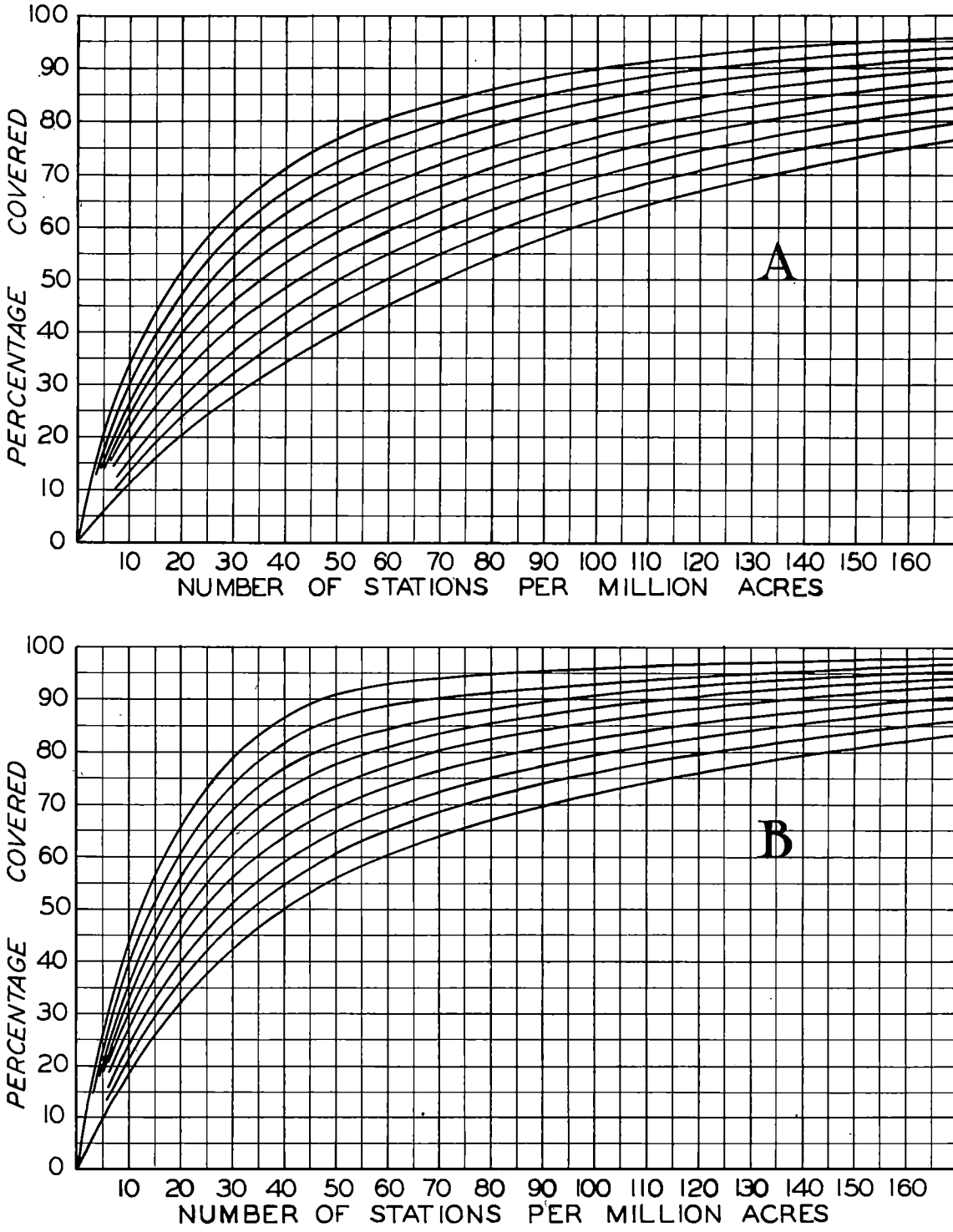


FIG.21 SMOKECHASING COVERAGE
OF FUELS WORSE THAN AVERAGE
ACCORDING TO SPACING OF MAN-POWER STATIONS
UNDER TRAVEL TIME STANDARDS REQUIRED -
A- WHEN BURNING CONDITIONS ARE IN WORST CLASS
B- " " " " " AVERAGE "

COMPLETENESS OF COVERAGE

Several factors should be pointed out which in the practical application of plans have been found to lower the standards assumed to be in effect. One of these is road and trail maintenance. If maintenance is not done so as to permit the speeds of travel assumed in planning, action will be slower than planned. Telephone maintenance also is involved in speed of action. Another factor is mode of travel. For all stations on roads automobile travel was assumed in planning; if automobiles (in good condition) are not used, the distances reached in a given length of time will fall far short of those planned.

If plans for 100 stations per million acres have been approved and only 80 are manned, it is obvious that the standards have not been met. A similar condition, the effect of which is not so obvious, is encountered in plan work. The standards may not have been met because of failure to plan the same degree of coverage for areas similar in danger. Any set of travel-time specifications can be modified by the fire-control manager, or by the planner, simply by completing coverage to the degree he chooses. The important point is that argument regarding satisfactoriness of any travel-time specifications can lead to no useful conclusions unless the completeness of coverage to be worked out is included in the argument.

The economical impossibility of seeing and of reaching within travel-time allowances 100 percent of any large area has been discussed in connection with figures 20 and 21. Planners must be given a limit of completeness at which to stop adding coverage in each of the services of control. This is equivalent to saying that some sort of limit must be placed on the mileage of roads, and the number of firemen and crews allowed in different localities. In areas where a 60 percent smokechaser coverage has been put into effect, twice the allowable travel time will be required to reach many small areas which in total make up the uncovered 40 percent of area. With 80 percent of a large area covered, a 10 percent increase over allowable travel times will reach almost every spot. Limits based on overtime required were found easy to apply and were used as guides to desirable completeness of coverage.

A limit used in deciding whether or not an additional fireman station was justified in any locality was based on the quantity of danger (integration of fuel danger, frequency of fire occurrence, and probable damage) existing in the new coverage under consideration. Unless in the area added to detection coverage plus that added to smokechasing coverage a total of 16,000 or more danger points were found, the station was discarded. After applying this limitation, it was found that the detection and smokechaser coverages for whole forests ranged from 40 to 90 percent. Following an administrative decision in 1935 to increase efforts everywhere to control every fire in the first work period, a considerable increase over the number of stations thus limited was made for occupancy during the prevalence of most severe burning conditions. These additional

fireman stations were selected to cover the largest areas (particularly those containing dangerous fuels) shown uncovered on detection and smokechaser composites. Road and man-power plans that had been worked out for light reinforcement action were put into effect to a much greater extent than previously.

In table 14 the coverage planned for each forest in each of the four services of fire control, detection, smokechasing (initial attack), light reinforcements, and heavy reinforcements is shown. In order to make comparisons between forests these four coverage percentages were averaged, equal weight being given to the importance of each service. The standards used in obtaining these percentages are those applicable to a burning severity corresponding to class 5 of the Danger Meter, which represents the least severity in the class of burning conditions called "Maximum." This table is presented primarily as an example of what was done. The percentages have been changed somewhat and they will continue to fluctuate with additions of roads, changes in planned road locations, and with annual and intra-seasonal decisions whether or not to man certain fireman and crew stations. It should be pointed out that the percentages of coverage shown apply to fuels worse than average. Larger percentages would be found for areas as a whole, disregarding fuels.

PROTECTION THAT CORRESPONDS WITH DANGER

A statement believed to be axiomatic is that no danger exists except where values exist, and the greater the values threatened the greater is the danger.

The fact must be recognized that a conflagration is likely to originate almost anywhere and any conflagration threatens a very large area. Hence, if probable damage is recognized in degree of preparedness, such recognition must be on a large area basis. With this in mind, the relative average danger ratings of whole national forests are shown in the last column of table 14 where they can be compared with the average percentages of coverage worked out in planning. It will be observed that the average percentage of area covered (as planned) in different forests is somewhat proportional to the average danger. The coverage percentages shown do not include the stations added in 1935 to meet most severe burning conditions, but include only those that passed the test of covering 16,000 or more danger points.

Since probable damage can be recognized only on a large area basis, the inclusion of values in rating the relatively small area covered by a particular station leaves the problem of threats in low-value areas containing dangerous fuels partially unanswered. Such ratings also tend to leave large areas of uniformly low-danger fuels without any coverage whatever. In final analysis it was found necessary to make judgment decisions as to the addition or rejection of more stations for fireman and reinforcement crews and more roads.

A possible method of evaluating the relative average danger in different large areas is to determine for a long period of years the expense and damage caused by the average fire and multiply this by the number of fires. If available or proposed funds were distributed on this basis, planners could disregard values and build up coverages in each service of control to best advantage according to fuels and frequencies of fire occurrence within different areas, until the limit placed on funds stopped further additions. This method of rating danger was the first one tried and, while it may be applicable in some regions, it failed here because of the necessity for making allowances in some areas for the strong influence of errors in action on costs of suppression and damage.

Considering the intangibility of fire damages, it would probably be easiest to reach agreement on relative danger in different areas by obtaining judgment decisions of three experienced men assigned to study the best information available on fuel conditions, long-period frequency of fire occurrence, and probable damage. From the planning experience gained in this project, and from the danger ratings worked out and shown in table 14, it appears that all large areas of the northern Rocky Mountain region, disregarding national forest boundaries, could be grouped into three danger classes. For each danger class of area it would be logical and desirable to specify the degree of coverage considered necessary in each service of fire control. Each of the three classes of area thus recognized in this region probably is similar in danger to large areas in other regions, and through correlations the relative position of this region's three classes in a total range of perhaps 10 classes could be determined.

It should be recalled here that the present objective of fire control is the same for every part of every national forest, to control every fire within the first work period. The unavoidable question must be faced. Why have some areas been left with less fire-control strength than others? The answer is that over a period of 30 years through analyses and group opinions, strength of fire control preparedness in different large areas was adjusted to estimated danger. Although preparedness has been strengthened everywhere, the relative strength in different areas is still governed to a large extent by probable danger.

It should be realized that what is purchased by investments and annual expenditures for fire control is coverage of areas. In attempting to be efficient it appears logical to plan and establish the degree of protection desired, which means no more or less than specifying the degree of coverage needed in different large areas in each of the services of fire control, detection, initial attack, light reinforcements, and heavy reinforcements. In final analysis such a statement constitutes a definite objective which in time can be adjusted to conform to tolerable burned area and to the least total of cost and loss.

Table 14.--*Percentage of fuels worse than average in each western national forest of Region One covered by each service of fire control as planned for "Maximum" 1/ burning conditions.*

Forest and extent of development of roads, trails, and landing fields	Detection	Initial attack	Reinforcements: Light	Reinforcements: Heavy	Average percentage covered	Relative danger rating 2/
	Percent	Percent	Percent	Percent	Percent	
WITH 1934 TRANSPORTATION ROUTES						
Nezperce	47	53	76	42	55	1.2
Selway	75	41	38	28	46	2.1
Clearwater	81	73	65	40	65	2.4
St. Joe	79	81	79	72	78	2.3
Coeur d'Alene	72	76	98	98	86	3.1
Pend Oreille	66	79	98	84	82	2.4
Kaniksu	85	77	94	91	87	3.1
Kootenai	57	54	96	42	62	2.1
Blackfeet	52	70	91	44	64	1.3
Flathead	66	57	64	19	52	0.9
Cabinet	71	75	98	85	82	1.3
Lolo	55	61	86	82	71	1.6
WITH PLANNED TRANSPORTATION ROUTES						
Nezperce	49	65	94	55	66	1.2
Selway	79	49	96	51	69	2.1
Clearwater	83	81	100	86	88	2.4
St. Joe	79	83	99	91	88	2.3
Coeur d'Alene	74	80	98	100	88	3.1
Pend Oreille	76	88	99	94	89	2.4
Kaniksu	85	84	98	97	91	3.1
Kootenai	61	59	99	84	76	2.1
Blackfeet	52	73	99	51	69	1.3
Flathead	69	57	88	27	60	0.9
Cabinet	71	75	99	96	85	1.3
Lolo	55	62	99	96	78	1.6

1/ Corresponding with a Danger Meter rating of class 5.

2/ Relative danger ratings are for entire areas included within protection boundaries regardless of ownership.

In order to be prepared with any degree of coverage desired, plans for roads and man power were worked out by steps of completeness.

After a large coverage has been put into effect, an increase even as small as 0.1 percent is very expensive. Since satisfaction of the objective necessitates recognition of rate of spread, rate of work (fuels), and burning conditions, expenditures for determining these influences might easily yield greater returns than expenditures for increased coverages.

Until the desired degree of coverage is stated, it will be impossible to state the planned cost of fire control. The form used in summarizing costs is shown as figure 15.

SUMMARY

Standards of action necessary to control almost every fire in the first work period were set up. These standards were based on evidence of success and failure obtained in an exhaustive analysis of fire records.

Fuels, the materials in which fire control engineers operate, were classified and mapped. Probable damage was appraised. Frequency of fire occurrence was determined. Assuming danger to be a composite of these three influences, an integration of them was made in order to evaluate relative danger per acre.

By studying many possible combinations of existing and proposed roads in relation to man-power stations, a combination believed most satisfactorily to cover the danger was determined. Such a combination was planned for use under each of four degrees of burning severity.

By changing detection and smokechaser stations, from those previously occupied to those selected in planning, the areas of national forests covered were increased in amounts ranging from 12 to 22 percent of the whole areas.

It was found to be economically impossible to cover 100 percent of any large area with detection and with the speed and strength of attack specified by the standards adopted. Extremely high costs are involved in the decisions, which have not yet been made, as to degree of coverage to be provided when burning conditions are most critical. Since experience and investigations are insufficient to indicate the relation between degree of coverage and degree to which the objective is satisfied, an interesting and highly important field is open for research.

In reporting progress to date a great deal of satisfaction is derived from the facts that in recent years expenditures and preparedness for fire control have been increased greatly under every degree of burning severity and, through planning, the entire structure has been strengthened systematically.

Table 15.--*Form used in summarizing costs of fire control.*

_____ National Forest

ACREAGE

Total acreage presumed to be afforded adequate protection by the fire control organization recommended: _____ Acres.

Item of cost	Average annual cost	
	Total	Per acre
	$	¢
Direct:		
Average Condition (Regular) Protection Organization - Temporary force only $_____		
Minimum Condition Organization $_____		
Class 5.1 to 6 Emergency Overload Organization $_____		
" 6.1 to 7 " " " $_____		
Indirect:		
Maintenance Plus Amortization Costs - F.C. transportation equipment, packstock, tools, K & M, and all forms of protection organization equipment costs		
Salary and Expense of Year-long Forest Personnel Chargeable to Prevention and Presuppression		
Regional Office Indirect (Average from activity cost accounting summaries)		
F.C. Improvements:		
Structures of all types. Annual Amortization Plus Maintenance Cost - Existing $_____		
Proposed $_____		
Trails - All Classes - Annual Amortization Plus Maintenance Cost - Existing $_____		
Proposed $_____		
Roads:		
Amortization Plus Maintenance Existing $_____		
Proposed $_____		
Total:		
Cost of Maximum F.C. Organization Contemplated		

Recommended for approval:

_____, 193__ _____

Date Forest Supervisor

PART II
DETAILED PROCEDURES IN PLAN WORK

INSTRUCTIONS FOR FUEL-TYPE MAPPING

For efficient forest fire control, it is necessary that intensity of attack on fires vary with probable rates of spread and with probable resistance to control. These are determined principally by weather conditions and fuel conditions. Methods of measuring fire-weather conditions over large areas have been worked out for the northern Rocky Mountain region, and ratings of local fire danger are being made daily during the fire season for many localities of the region. The next step in providing fire-control planners and dispatchers with the information they need is to prepare maps indicating what speed and strength of attack will be required to suppress fires occurring on given areas under a given degree of weather danger.

In this and other regions, many very detailed inventories showing the quantity and character of green and dead fuels and their exposures have been taken, and attempts have been made to base fire-control plans on later interpretations of these inventories. Thus far, this method has not been satisfactorily applied. In the method described here, no detailed inventory of physical conditions is recorded; instead the man on the ground, at the time of observing fuel conditions on an area, makes and records an estimate of probable rate of fire spread and probable resistance of fire to control. The principal factors observed are kind, quantity, arrangement, and continuity of fine fuels and the exposure of such fuels to sun and wind. These are the factors that, together with weather conditions, determine a fire's rate of spread, that is, the number of chains of perimeter it produces per hour, and its resistance to control, that is, the number of man hours of suppression work it requires per chain of perimeter. Obviously, the number of man hours required per chain multiplied by the number of chains to be worked gives the firefighting job to be done.

SELECTION AND TRAINING OF MAPPERS

Fuel mapping is to be done by men having wide experience in the control of small fires, or by others who have been thoroughly trained by such men. An observant man can quickly learn to classify fuel conditions correctly, even if inexperienced in fighting fire, through supervised field study of typical conditions described and classified in these instructions (p. 100). Experience has shown that for best results a trainer should instruct mappers in groups of not more than 6. He should guide the men in practice mapping until individually they can give consistent and accurate ratings to the different fuel conditions observed. Trainees should be encouraged to argue ratings. In this way comparisons with other fuel conditions are brought out.

It has been said that the best possible fuel mapper would be a man who had suppressed many small fires under many conditions but had never seen a large fire. The idea behind this statement is that anyone who has been strongly impressed by some experience with a large fire is likely to overestimate the probable rate of spread represented by certain fuels, unless he remembers clearly the conditions of drought and wind in which this fire took place and its initial rate of spread. Men who have previously given efficient service as lookouts and smokechasers and who have an inquiring turn of mind usually learn most rapidly and do the best work.

Because of the value of the resources at stake in fire suppression and the expense of fire-control operations, fuel mapping is highly responsible work. The mapper assumes part of the responsibility for correct suppression action. Integrity and a high degree of consistency in drawing conclusions are essential qualifications.

FUELS AND CONDITIONS CONSIDERED

The fuels considered by fuel-type mappers are fine materials such as tree branches less than 1 inch in diameter; shrubs and herbaceous plants; loose, rotten wood and bark; frayed, broken trunks; checks, moss, dead needles, and loose, rotten bark and wood on windfalls and on standing trees, living or dead; and needles, leaves, duff, weeds, grass, and moss on the ground.

The travel time allowed a fireman is determined by conditions of fuels. On areas newly logged or recently burned, fuel conditions become worse rapidly, and consequently it is necessary to shorten travel times and relocate stations. If fuel mapping is being done for the purpose of planning location of man power and roads, it is necessary to predict the condition of changing fuels so that correct coordination will exist several years later. Maps made for the purpose of dispatching men to fires should show the present condition of fuels and should be revised annually for any areas on which conditions have changed conspicuously.

Ratings represent fuel conditions existing after a month of continuous midsummer drought.

The influence of frost-killed vegetation is disregarded.

Ratings refer to small fires only; after fires have attained speed their spread is not appreciably influenced by small differences in factors such as fuel moisture or protection from wind. Attention is focused on what a fire is likely to do in the first two or three hours after it becomes large enough to be discovered by a lookout, that is, during the time required for travel and control by smokechasers.

RATE OF SPREAD

The fuel-type mapper is expected to consider all the different initial rates of fire spread that commonly occur in the northern Rocky Mountain region after a month of drought, divide them roughly into three equal classes called low, medium, and high, and assign each area he encounters to one of these classes. A fourth classification, extreme, is reserved for areas on which spread would be exceptionally rapid.

"Extreme" rating applies primarily to the worst parts of blow-down, slash, and snag areas. It must be given where a dense stand completely wind thrown is fully exposed to sun and wind. This classification is applicable to exposed slopes densely covered with cheat grass, but not to any other pure grassland condition.

The more difficult of the generally distributed fuels on an area determine its rate-of-spread classification. If an area is approximately uniform in fuel conditions with the exception of spots containing worse fuels, the spots should be classified separately. If spots contain fuels of high or extreme rate of spread, these spots should be shown even if the map scale necessitates exaggeration of their true size.

Where a large fire has stopped naturally the mapper should not assume that this is accounted for by the quantity and kind of fuel present, under drought conditions. Very often a fire's dying out has resulted from precipitation, high humidity, change of wind direction, night cooling, or a combination of these factors, rather than from fuel conditions.

Evidence as to causes of differences in rate of spread has been obtained through forest research in widely separated regions of the United States. This evidence is in the form of statistics based on measurements of fuel moisture content, solar radiation, and wind movement as influenced by shade, by obstructions to air movement, and by direction and degree of slope.

INFLUENCE OF TREE OR BRUSH COVER

At the Priest River Experimental Forest, in northern Idaho, Gisborne has established three fire-weather stations about 500 feet apart in a line approximately parallel to the prevailing wind direction, southwest to northeast. All are on a flat originally covered by a dense overmature stand of the white pine-hemlock type. The station farthest south is on an area that has been clear cut and is now fully exposed to wind and sun. The next is at about the center of a 500-foot strip where cutting has reduced the density of the forest canopy to half. The third is 300 feet within a portion of the old-growth stand immediately northeast of the half-cut area. It is evident that after a month of continuous midsummer drought most of the differences in daily weather records at the three stations must be attributed to differences in density of stand. Records taken at these stations in the week August 10-16, 1931, were

selected for study, because that week was in the worst part of a disastrous fire season and was without precipitation.

For that week, figure 22 shows the average hourly readings of temperature just under the surface of the duff and of relative humidity in the instrument shelter, 4.5 feet above the ground, on the clear-cut, half-cut, and full-timbered plots, respectively. Readings varied very little from day to day. During the daily period from 7:00 a.m. to 4:30 p.m. temperature was high and humidity low according to density of stand; in other words, inflammability of fuels varied according to density of stand.

Although afternoon relative humidities of the air 4.5 feet above the ground were much alike for the three plots, considerable differences existed in afternoon moisture content of fine fuels at or near the ground surface. The daily trends of moisture content of half-inch wood cylinders 10 inches above the ground are shown in table 17. Finest fuels, such as grass, moss, and duff, can be ignited with a lighted match at times when adjacent half-inch wood cylinders contain less than 8 percent moisture, and are distinctly more inflammable when the cylinder moisture content drops below 6 percent. In full timber, the moisture content of cylinders 10 inches above the ground sank to 8 percent shortly after 9:00 a.m. and was a little more than 6 percent at 4:30 p.m. On the half-cut area it was down to 6 percent even at 9:00 a.m., and on the clear-cut area it was still lower. Thus, regardless of wind influence, the rate at which a fire consumes fine fuels is definitely related to openness of stand.

Table 17.--*Moisture content of wood cylinders and rate of wind movement according to density of timber stand, at Priest River Experimental Forest* 1/

Plot	Average moisture content of ½-inch wood cylinders 10 inches above ground		Average wind velocity 4.5 feet above ground	
	9:00 a.m.	4:30 p.m.	5:00 p.m. to 9:00 a.m.	9:00 a.m. to 5:00 p.m.
	Percent	Percent	Miles per hour	Miles per hour
Clear cut	5.3	2.4	1.2	3.8
Half cut	6.0	4.4	0.6	2.3
Full timbered	8.7	6.1	0.1	0.2

1/ Data are for the week August 10-16, 1931.

The relative-humidity data shown in figure 22 represent average daily conditions in the northern Rocky Mountain region during periods when severe burning conditions prevail. Previous to the week studied conflagrations had occurred within 20 miles on one side of the Priest River forest and within 5 miles on the opposite side, and no rain had occurred to improve conditions. Relative humidities lower than those shown occur in the region frequently.

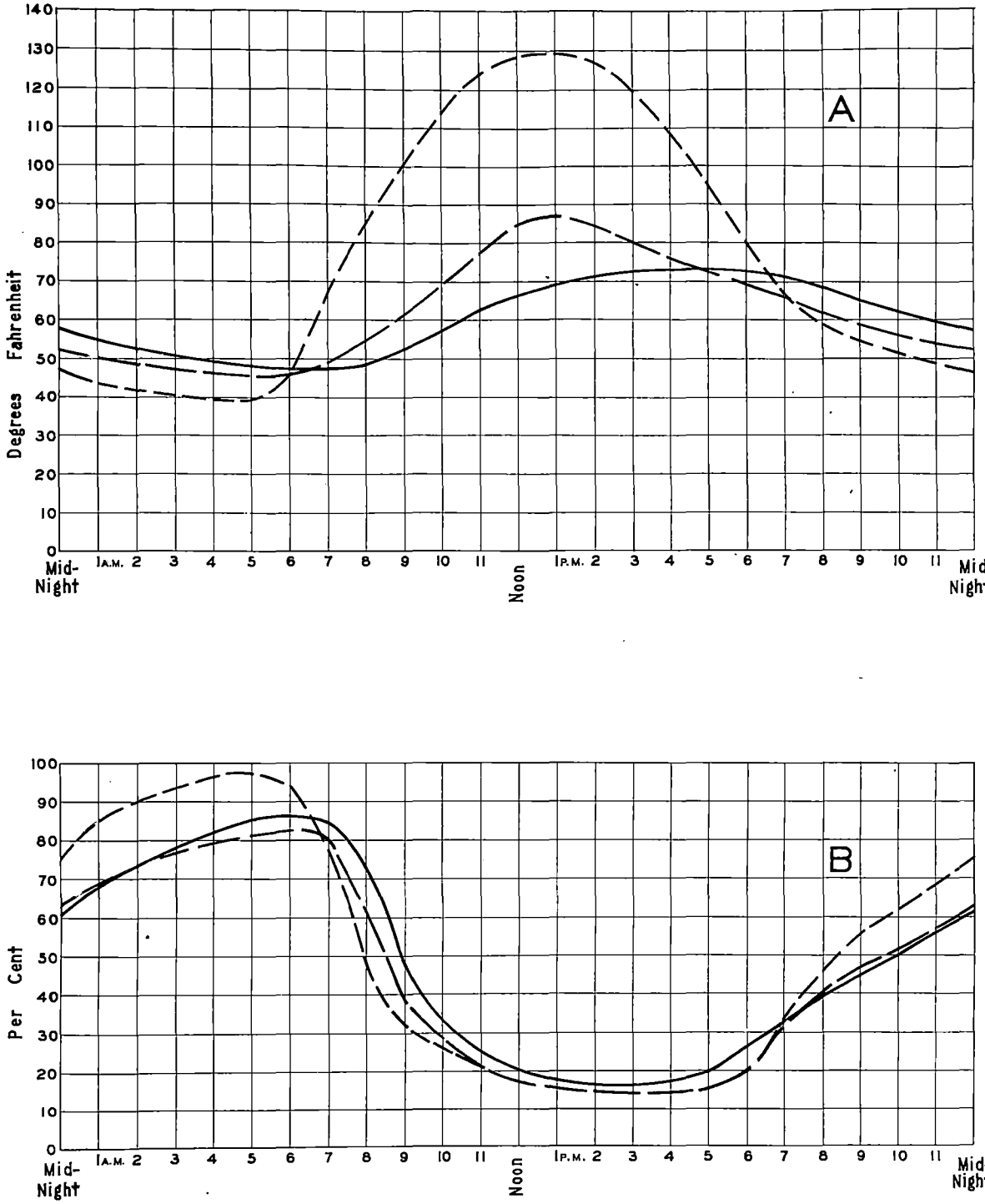


Fig. 22.--Average hourly weather readings during week August 10-16, 1931, according to density of timber stand, on Priest River Experimental Forest: A, Temperature just below duff surface; B, Relative humidity 4.5 feet above ground.

Full-timbered plot _____
Half-cut plot _ _ _ _
Clear-cut plot --------

thus the exposure receiving the greatest radiation at Missoula is a south-facing hillside with slope of 26^{0}, or 52 percent. Shade cast during a portion of the day by mountains reduces the radiation received in many places. Allowance for this condition must be made by fuel mappers.

A simple and practical way to judge the intensity of solar radiation on any surface is to imagine a long straight tube reaching from the earth's surface toward the noon position of the sun. The sun's rays coming through this tube will spread over a greater area according as slope differs from the perpendicular to the tube. The greater the concentration of rays per square inch (or per acre), of course, the greater will be the heating effect of solar radiation on fuels.

INFLUENCE OF FOREST TYPE

Figure 18 on page 69 of Part I shows for cut-over areas and for green, uncut pole-size or larger forests of each timber type in the northern Rocky Mountain region what percentages of fires in the 10-year period 1921-30 spread at given initial rates. The rates shown are averages for the period between hour of discovery and beginning of attack. 11/

It will be observed that rates of spread within the range shown varied according to natural openness of timber stand. The greater the openness of the stand, the greater was the proportion of fires spreading at rates bordering on the dangerous. The brush-grass type is the most open and occurs in the most exposed situations. Spruce, white fir-cedar, and cedar-hemlock grow in the most protected situations and are most dense. Intermediate between these are the ponderosa pine, larch-Douglas fir, Douglas fir, lodgepole pine and western white pine types. The subalpine type is affected by too many variables to be included in general comparisons. In the two most open types, brush-grass and ponderosa pine, 10 percent of the fires spread at an average rate of 15 chains or more per hour; in the two most dense types, white fir-cedar and spruce, less than 2 percent spread at such a rate.

A study of factors important to fuel mappers was made by Bates *(2)* on a "transect of a mountain valley" in the central Rocky Mountain region. Fuel mappers in the northern Rocky Mountains can make many legitimate inferences regarding probable rate of fire spread in different forest types and situations from the following portions of Bates's conclusions:

"A transect of this valley (700 feet wide, with axis in an east-west direction) was made, running as nearly as possible normal to the contours of both slopes, in a straight line and on this line stations were located arbitrarily at intervals of exactly 50 feet. The valley walls on either side attain a gradient of about 45 percent, or 25^{0}, the steepest portion, as usual, being near the middle of either slope.

11/ Usually an aggressive fire spreads not uniformly but at an irregularly increasing rate. If the perimeter is 10 chains at the end of the first hour and increases with an acceleration of 10 chains per hour, per hour, the perimeter is 30 chains at the end of the second hour. The average rate of spread for the 2 hours is then 15 chains per hour, but the actual rate at the end of the second hour is 20 chains per hour.

Findings agreeing with those presented here were arrived at by Stickel *(20)* in the Northeast.

A dry prevailing wind dries fuels and prepares them for more rapid spread of fire, and wind movement at the time of a fire increases rate of spread by supplying oxygen for combustion and by carrying hot air to unignited fuels. Evidence of the effects of wind movement appears in figure 22. On the full-timbered plot, where air that became heated could not move freely, temperature continued to rise in late afternoon, while on the clear-cut plot, where air was free to circulate, it was falling. Records of wind movement according to openness of stand are shown in table 17. Although the wooded strips protecting two of the weather stations were not wide, the average midday velocity of wind in the open was cut to 60 percent on the half-timbered area and to less than 6 percent in the full-timbered. Undoubtedly, on both these areas the air above the tree tops was moving as fast as it was at the height of the instrument shelter on the clear-cut area.

Because of the fact last mentioned, fuel mappers should be careful to observe the condition of any fine and continuous fuels in the tops of dead or green crowns. Moss, dead needles, or loose rotten bark and wood on stag-topped trees or on snags at the general canopy level of a stand have the same effect on a fire's rate of spread as such material on the ground in the open, except that humidity is usually greater in the canopy.

INFLUENCE OF SLOPE AND TOPOGRAPHIC SHELTER

The influence of wind on spread of fire varies not only with character of cover but with slope and topographic shelter. In the northern Rocky Mountain region the prevailing wind direction is from southwest to northeast, and only rarely are fires or fuels affected by general winds of any other direction. Local topography may change the direction of prevailing wind, however. Fuel-type mappers must endeavor to detect any local wind influences on inflammability and fire spread.

In some situations, for example at valley intersections, north slopes are not always protected from drying winds.

Species and condition of vegetation frequently indicate the existence or nonexistence of dry prevailing winds.

Air temperature at and near the ground and moisture content of fuels, likewise, vary with slope and with topographic shelter. Obviously, south slopes that are bombarded by the sun's rays all day and are perpendicular to them about noon receive the greatest possible quantity of solar radiation per day. North slopes, if extremely steep, receive little or no direct sunlight. Kimball *(11)* has calculated and tabulated the quantities of solar radiation received during different months in the United States according to slope, latitude, and altitude. The sun's greatest altitude on July 15 at the latitude of Missoula may be considered representative for the northern Rocky Mountain region. This altitude is 64°;

"All of the south exposure is subjected to direct insolation at some time during the day and during the entire year. As a result of this insolation, high maximum temperatures are recorded at the surface of the soil, the highest during 1921 being nearly 150° F., and being fully 60° above that of the coolest neighboring site.

"We incline to the belief that this temperature of 149° F. would kill outright any yellow pine seedlings less than 2 months of age, and certainly any seedling of other species at any time during the first growing season.

"The extreme top portion of the south exposure, which Douglas fir is capable of invading, shows almost as thorough drying of the surface soil as any other portion, but appreciably lower temperatures.

"From the bottom of the valley to almost the top of the north exposure relatively moderate temperatures are experienced, both on account of the angle of incidence of the sun's rays and the completeness of the cover. On the lowest and also steepest portion of the north exposure, the evaporation rate is lowest, the soil temperatures are lowest, the accumulation of moisture is greatest, and the drying of the soil is most gradual. So far as these are the results of steep slope, the conditions would probably exist in a degree if all cover were removed.

"The upper portion of the north exposure becomes progressively warmer and drier. Here, evidently are encountered about the mean temperature conditions which are favorable to Douglas fir. But it should be noted on all similar exposures, once the Douglas fir forest is established, there is a marked tendency for Englemann spruce to invade and supersede fir."

It should be noted particularly that Bates found the naturally open stands in situations where weather influences promote rapid spread of fire. According to the evidence from other studies presented in the foregoing, openness of stand, whatever its cause, itself conduces to rapid spread of fire. The inference is justified that natural openness of stand is a stronger indication of high potential rate of fire spread than openness caused by thinning a naturally dense stand. In the latter case, however, failure to remove fine fuels that were parts of the trees taken out may increase the potential rate of spread greatly. In making comparative ratings of fire spread according to forest type and exposure, mappers are cautioned to consider similar conditions of volume, continuity, and fineness of fuels.

Bates found that at the foot of the south exposure described in the foregoing quotation ponderosa pine is struggling for existence on the almost unforested area, that farther up the slope Douglas fir is invading the ponderosa pine area, and that on the north exposure spruce

is invading the Douglas fir area. It seems evident that the shade and protection from wind afforded by trees not only effect a direct limitation of inflammability but make possible a still more dense and less inflammable stand.

Comparisons of timber types should be confined to normal green stands of pole size and larger, free of such abnormalities as those caused by insect epidemics, burns, logging, and blow-down.

It must be remembered that timber type alone does not determine probable rate of fire spread on a specific area. Type simply indicates the local status of some of the factors influencing rate of spread. Age of stand in combination with quantity and condition of older, intermixed dead and green trees means much. Usually conditions that exist within a stand of any age are complex. Many a stand that contains less than 200 trees per acre when 200 years old originally contained more than 2,000 trees per acre. The fuel mapper cannot know without careful examination whether or not the casualties and other dead material from partial cuttings or from still older stands are present. He should refrain from classifying fuels on and near the ground unless he can see them at least with field glasses. Even if a crown is rather open, he cannot see through it from outside.

INFLUENCE OF PREVIOUS BURNING, CUTTING, AND BLOW-DOWN

Since fires of any size in this region usually kill the entire stand, it might be expected that fire would always spread much faster in stands previously burned than in green stands of the same type. Such a tendency was exhibited only by the fastest-spreading 15 percent of the 1,536 fires recorded as originating on single burns during the 10-year period 1921-30. In other words, if weather and fuel conditions were critical initial spread was faster on single burns than on unburned areas of the same forest type, but under average burning conditions no differences were observed. The term "burn" was applied to large areas having a more or less dense cover of brush and reproduction not more than 30 years old. The statistics seem to prove that such growth shades fine fuels and prevents air movement around them, although not so completely as mature timber stands.

Decision as to probable influence of snags on rate of spread is very difficult. In order to estimate the probability that fire will run between snags it is necessary to examine the fuel on the ground at their feet and between them. The kinds of fine fuel present on snags determine their inflammability and the likelihood that fire will be spread by sparks flying from them. The distance between snags and their exposure to wind determine the probability that fire will spread from snag to snag when cinder material is present. Under ordinary conditions of wind and snags on gentle slopes, fire is not likely to spread between snags that are more than 50 feet apart.

Between burned areas and unburned clear-cut areas, both fully exposed, there is usually a great difference as to quantity and continuity of fine fuels near and on the ground. Bare spots are frequent on the former and rare on the latter. Past cutting operations have usually produced a high degree of openness in stands. When a complete set of curves was made, by timber types, for initial rates of spread of the 1,125 fires of 1921-30 that originated on cut-over areas, it was found that the rates of spread, throughout their range, for every forest type, greatly exceeded those of green forest and single burn. It was found also that the relative order was the opposite of what it was for uncut stands; that is, rates were lowest for the most open types bearing the smallest quantities of foliage per acre and were highest for the most dense types. The differences in rate of spread according to timber type were small. On cut-over areas rates were found to correspond more nearly to method and degree of slash disposal than to timber type. On cut-over areas mappers should observe carefully the volume and continuity of slash as well as the degree of openness caused by removal of trees.

RESISTANCE TO CONTROL

Resistance to control, as stated previously, is an expression of the quantity of suppression work required per chain (or other unit) of fire perimeter. Resistance is rated according to the same classification as rate of spread -- low, medium, high, and extreme. An outline of the important factors in resistance follows:

Fine fuels present in
- standing green timber
- snags
- windfalls and slash
- brush, reproduction, and grass
- duff and roots

Quantity
Arrangement
Size
Species
Decay

Trenching and dirt-smothering chance as affected by

Roots
Soil
Rocks
Slope

In estimating probable resistance the fuel mapper will assume the method of attack to be ordinary handwork with the most suitable tools. He should endeavor to visualize an efficient fireman doing whatever work would be needed at the spot under consideration.

The rating will represent only the work required to corral a fire and hold it through the midday burning period. In situations such as under dense old stands, particularly on north slopes and protected flats, much work is required to extinguish a small fire burning in deep duff and rotten logs but relatively little work suffices to prevent its escape. Under such conditions escape cannot take place except by way of fine fuel connecting fuel on the ground with fuel in the tree tops. A connection may be afforded by dead, moss-covered limbs hanging nearly to the ground, mossy green foliage, or green hanging branches that bear considerable quantities of dead needles and buds. During drought periods, a little heat suffices to dry green coniferous foliage to the point at which it will ignite.

It is frequently easier to prevent escape of a fire burning in a tangle of large logs, by clearing fuels away from them and smothering fire with dirt, than it is to prevent escape from a tangle of small logs.

In places, the mapper will recognize that the potential fire-suppression job consists principally in felling a single burning snag. In such a case the resistance should be thought of as the quantity of felling work per snag plus the work caused by transmission of sparks to the material in which the snag would fall and by possible new fires spreading from burning cones and chunks rolling down steep slopes. In yew brush, particularly, such new fires are difficult to control.

STANDARD RATINGS OF 43 TYPICAL CONDITIONS

At five training camps for fuel mappers 90 men, representing 10 national forests, agreed on ratings to be assigned to 43 sets of conditions typical for the northern Rocky Mountain region. The conditions and ratings are listed in table 18. These examples have proved adequate as a basis for training fuel mappers to rate correctly and consistently all the fuel conditions encountered in the northern Rocky Mountain region.

Table 18.--*Classification 1/ of 43 fuel conditions, typical for the northern Rocky Mountain region, as to probable rate of fire spread and probable resistance of fire to control.*

Example number	Fuel condition	Rate of spread	Resistance to control
1	Mature larch-fir, white pine, or lodgepole on protected flats or northeast slopes, where windfall is light and not continuous; stand dense enough to shelter fuels on ground. Ground vegetation conspicuously low shrubs throughout. Trees clean and snags few. Tree moss may be moderate	L	L
2	If stand is exposed to almost full sun and wind has moderate access to ground	M	L
3	If windfall and snags are moderate but conspicuous and mixed with thin but continuous grass carpet and stand is exposed to wind and sun	M	M
4	If windfall and snags are moderate to heavy, continuous and intermixed with only scattered trees of the old stand, and reproduction does not fully shade windfalls On protected NE slopes	M	H
5	On exposed SW slopes	H	H
6	If these same mature stands were burned over by light fire, or were heavily bug-killed, resulting in dense reproduction 20-30 years old, not completely shading windfalls and mixed with very heavy accumulation of limby windfalls and continuous rotten, broom-topped, or otherwise inflammable snags 50-75 feet apart On protected NE slopes	H	E
7	On exposed SW slopes	E	E

1/ E = Extreme, H = High, M = Medium, L = Low.

Example number	Fuel condition	Rate of spread	Resistance to control
8	Single burn in very heavy overmature stand of hemlock and cedar, on exposed flat and gentle south slope. Windfall very heavy, and cluttered with limby tops broken from snags. Grass conspicuous in patches. Snags to the extent of one-third of original trees remaining, mostly with broken tops and full of limbs. Aerial spread by sparks is expected	E	E
9	If small limbs of above stand had been consumed by a hotter fire, or if stand were on north slope or protected from wind	H	E
10	Hemlock: old sale areas where heavy stands were girdled and trees have now broken off in several sections, mixed with wind-thrown trees. Much fine fuel on ground. Snags numerous and broom-topped. Most exposed places	E	E
11	If partially protected from sun and wind, and fuel moderate in amount	H	H
12	Hemlock and white pine, overmature, with mixture of larch-fir. All species very defective. Scattered snags and windfall. Moss conspicuous. Many trees bushy to ground		
	On S slopes, with mossy, bushy trees	M	H
13	On N slopes, with mossy, bushy trees	L	H
14	On N or S slopes, without mossy, bushy trees	L	M
15	Hemlock: extremely dense stagnated reproduction of hemlock, cedar, and white pine 30-40 years old, on rolling S slope. Windfall heavy and limby. Recent windfalls have crushed reproduction. Snags of larch and cedar remain, mostly more than 50 feet apart	H	E
16	If stand is on a slope somewhat protected from wind	M	E
17	White pine 80 years to mature, 30% to 50% of trees bug-killed within past 10 to 15 years. Intermixture of spruce and larch-fir. On exposed, gentle to steep S slopes.	H	H

Example number	Fuel condition	Rate of spread	Resistance to control
18	White fir, about 50% dead, 80-200 years old, constituting 60% of dense stand of mixed ages and species. Trees bushy to ground. Fine limbs and dead needles already appearing on ground. Moss not conspicuous on trees. Exposed flats and gentle W slopes	H	H
19	Single burn 20 years old in white pine or larch-fir type, on exposed SW slopes, gentle to steep. Old stand all dead and most of it remaining as windfall, not yet shaded completely by well-stocked stand of reproduction	H	H
20	If on protected NE slope	M	H
21	Lodgepole, full mature stand 60% bug-killed and windthrown, on exposed flats and rolling ground	H	H
22	If on exposed S slopes, over 10%	E	H
23	Lodgepole, 1910 burn, windfall heavy but shaded by dense reproduction 15 feet high. On most exposed SW steep slopes	H	H
24	If on gentle and somewhat protected slopes:	M	H
25	Subalpine: dense, mossy fir; spruce, etc. with limbs thick to ground. Dead trees intermixed. Where fully exposed to wind and sun	H	H
26	On protected NE slopes, and fuels safe between trees	L	L
27	On fully exposed ridge tops, but free from moss and bushy green or dead trees. Carpet of shrubs on ground	L	L
28	Mixed brush, with large volume of windfalls and snags. Dense to medium ceanothus, willow or maple on SW slopes with dead brush and windfall conspicuous. Grass scattered in patches. Reproduction inconspicuous	H	H
29	If windfall and snags are only moderate	H	M
30	If dead brush, windfall, snags, and grass are inconspicuous	M	M

Example number	Fuel condition	Rate of spread	Resistance to control
31	Mature ponderosa pine, larch-fir, Douglas fir, or subalpine, open and conspicuously grassy, on fully exposed SW slopes. Windfall, slash, and snags almost absent	H	L
32	If stand is on protected flats	M	L
33	If intermixed reproduction is dense	H	M
34	If stand was heavy and was cut or killed leaving large amount of broadcast slash intermixed with much grass, needles, and snags	E	H
35	Thrifty young stands 40-80 years old of white pine, larch-fir, or mixed stands, including hemlock, cedar, and lodgepole, fully stocked or nearly so. Old windfalls and snags few and evenly scattered. Normal casualties due to crowding-out process and snow breakage, existing frequently as tangles up to 5 feet above ground. Stands dense enough to shut off wind and sun from ground, on any slope or exposure	L	M
36	Stand open enough to permit wind and sun to reach ground. On SW slopes, ridge tops, or upper parts of NE slopes	M	M
37	Same open stand on protected flats or lower portions of NE exposures	L	M
38	Spruce: mature dense stands on protected stream bottoms and flats. If many snags are present and trees are bushy to the ground and carry an accumulation of needles, twigs, and buds	L	H
39	If stand is normally exposed to considerable wind	M	H
40	If snags and bushy trees are so scattered that fire will not spread among them	L	M
41	If trees are clean, snags are almost entirely absent, windfall offers no problem, and fine fuels are almost absent	L	L

Example number	Fuel condition	Rate of spread	Resistance to control
42	White fir: old decadent stand on gentle S slope. Considerable moss, scattered dead trees. Fire likely to start only in white fir snags.....	L	M
43	Cheat grass, densely covering exposed slopes	E	L

LEGEND AND ILLUSTRATIONS

The legend used is shown on page 106. A sample of field work is shown on page 50 of Part I, and illustrations of fuels are shown by the frontispiece and on pages 52 and 55.

SCALE

Field work of satisfactory refinement cannot be done on maps of scale smaller than 1 inch to the mile, and no smaller scale is to be used. Fuel-type maps on a scale of 2 inches to the mile are needed by dispatchers, and this scale is consistent with the degree of accuracy to which locations of fires can be determined with lookout instruments. Since all plan work is done on maps having a scale of one-half inch to the mile, it is necessary that the field maps be reduced in the office to this scale. In making the office map, fine lines should be drawn with colored inks.

FIELD SUGGESTIONS

Fuel mappers should be required to use good-quality field glasses.

It is best always to decide on and record rate of spread first, since rate of spread has an influence on resistance to control.

Pending decision as to a final rating, a tentative rating may be recorded by writing on the map, with ordinary pencil, the initial letters of the class designations. Thus "HM" may be written for high rate of spread and medium resistance to control.

Where boundary lines between different fuels are conspicuous at the borders of burns, frequently they can be observed and mapped at a considerable distance more quickly than at close range.

The best place to observe the top of a dense crown canopy is from across a valley.

CURRENT POSTING

Mappers are expected to keep office copies of field maps posted currently, usually daily, with good protection from every possible agency of destruction. Protection is required because crayon rubs off and smears easily, and because there is always a possibility of getting the field map wet or losing it.

RATE AND COST OF MAPPING

In fuel-type mapping of 15 million acres of land in the northern Rocky Mountain region, the area covered per day by a man working alone ranged from 3 to 7 sections, averaging between 4 and 5 sections. Within the area accessible from roads the maximum per man day was found to be about 5,000 acres; where trails were the only routes of travel, it was not more than 2,500 acres. Mapping was facilitated by the high percentage of burned area in the region, which permits mappers to see over long distances. In dense stands of mixed species and age classes, slow progress must be expected.

The average cost of fuel type mapping on a scale of 1 inch to the mile ranged, among different large units, from $1.50 to $2.00 per 1,000 acres. If field work had not been pushed, in recognition of urgent need for the data in making fire-control plans, more detail could have been shown and the cost would probably have averaged about $2.00 per 1,000 acres.

If a map scale of 2 inches to the mile were used, as is desirable for obtaining the detail needed by dispatchers, the progress of mapping would be greatly retarded.

INSPECTION

A specimen inspection report on the form used in fuel-type mapping follows:

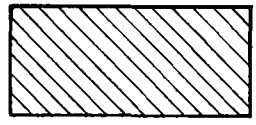
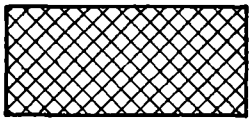
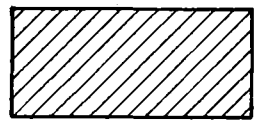
Mapping Procedure

Symbols Used

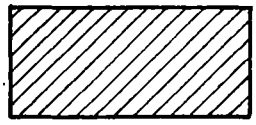
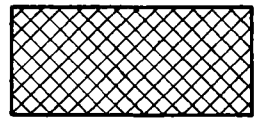
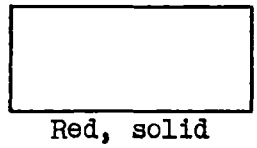
Colors

Blue	Extreme rate of spread.	Green	Medium third of rates of spread
Red	Highest third of rates of spread, except extreme rates.	Orange	Lowest third of rates of spread.

Line Directions

Solid color	Extreme resistance to control.		Medium third of resistance range.
	Highest third of resistance range, except extreme resistance		Lowest third of resistance range.

Sample Combinations

 Red lines	High rate of spread and low resistance.	 Orange lines	Low rate of spread and high resistance.
Green lines	Medium rate of spread and medium resistance.	 Red, solid	High rate of spread and extreme resistanc

Field Form *St. Joe* Forest

INSPECTION MEMORANDUM - FUEL MAPPING

Mapped by *John Doe* Date *8-2* 193 *3*
Inspected by *Richard Roe* Date *8-15* 193 *3*
Check Inspected by _____ Date _____ 193 __
Location of Area *Papoose Pk. to Bearskull, west and south of divide.*

Area checked *2370* Acres.

SUMMARY FROM REVERSE SIDE OF THIS SHEET
(Percentages are based on inspector's figures.)

Group	Fuel class: Rate of spread	Fuel class: Resistance to control	Total shown by inspector	Total shown acceptably by mapper	Total overrated by mapper	Total underrated by mapper
			Acres	Acres	Acres	Acres
	Extreme	Extreme				
	High	Extreme				
	Medium	Extreme				
	Extreme	High				
I	High	High	150	150		
	Medium	High	60			50
	Low	High				
	Extreme	Medium				
	High	Medium	110	110		
	Subtotal		320	260	0	50
	Medium	Medium	100	20		100
	High	Low	540	530	10	
II	Low	Medium				
	Medium	Low	1410	1360	40	
	Low	Low				
	Barrier					
	Subtotal		2050	1910	50	100
	Total		2370	2170	50	150
			Percent	Percent	Percent	Percent
% of Inspector's Group I area				81.2	0	15.6
% of Inspector's Group II area				93.2	2.5	4.9
% of Inspector's Group I and II area				91.5	2.1	6.3

Satisfactoriness of base map: Good ✓ Fair ____ Poor ____
(Check one)

Kind of map used: Scale 1" Topographic ✓ Planimetric ____
Accuracy of locating boundaries of fuels: *Satisfactory. Type lines on this area follow closely topographic features.*
Posting of office copy. Frequency of posting and satisfactoriness: *Posted to date and satisfactory.*
Rate of mapping progress and comments thereon: *Average about 4 sections per work day. Satisfactory under conditions on areas mapped.*
General remarks: *Work very good; carefully done; neat.*

The summary shown on the preceding page is based on the following data. This tabulation form is to be printed on the reverse side of summary sheets and inspectors are to be provided with an ample supply of blank forms.

CHECK RECORD OF INDIVIDUAL AREAS

Mappers' ratings		Inspectors' ratings		Mappers' acres			
Rate	Acres	Rate	Acres	Acceptable	High	Low	
HH	20	HH	20	20			
HH	30	HH	30	30			
HM	10	HM	10	10			
HM	30	HM	30	30			
HL	400	HL	360	360			
		ML	40		40		
HM	20	HM	20	20			
ML	1400	ML	1300	1300			
		MM	100			100	
HM	50	HM	50	50			
HH	100	HH	100	100			
HL	80	HL	70	70			
		MH	10			10	
MM	60	MM	0				
		MH	50			50	
		HL	10	10	10		
HL	100	HL	100	100			
ML	60	ML	60	60			
MM	10	MM	10	10			

The inspector will take off on tracing paper, in pencil, type areas and ratings shown by the mapper, and will orient this overlay over his map. For each area rated by the mapper the inspector will indicate his rating in the above spaces.

INSTRUCTIONS FOR SEEN-AREA MAPPING

The term "seen area," as used in the northern Rocky Mountain region and in these instructions, means the area that topography permits a fireman to see from a given detection station when the air is clear. The term "visibility" means the degree to which the atmospheric conditions existing at a given time, together with the contrast between objects, permit the human eye to identify the objects.

Existence of unseen spots is dangerous according as fires are likely to occur on these spots, the fuel conditions are dangerous, and the values at stake are high. The long discovery times of some fires occurring in unseen spots have caused failures in fire control. Obviously, failure to map seen areas correctly may result in serious fires.

A fire-detection station cannot be evaluated individually; it must be considered as one of a group. After a set of detection stations has been selected that satisfactorily covers the more irregular portion of a locality, it has often been found that this same set of stations satisfactorily covers all the remainder of the locality. Thus it may be entirely superfluous to occupy some prominent peak that an inexperienced man might have selected first.

Reliable seen-area maps must be made for many potential detection stations in order to sort out the smallest number of stations that, in combination, will give the desired coverage. To facilitate sorting, the areas seen from potential stations are traced, with black lacquer, onto sheets of a transparent material. Over a glass-topped table lighted from beneath, different combinations of seen areas are considered with reference to data on frequency of fire, character of fuels, and values at stake.

POTENTIAL DETECTION STATIONS FROM WHICH TO MAP

DEFINITION OF "DETECTION STATION"

Conditions at the top of a mountain occupied by a lookout are usually such that seen area may be somewhat enlarged by walking a short distance from the observatory. It would be impractical to require that a separate seen-area map be made for each of the detection points on a 100-foot patrol route. On the other hand, separate maps are necessary for points 1 mile apart. In general a detection station will be considered to include, together with the observation point considered at the time of mapping to be the most important, all the other points that lie within 5 minutes' walking distance from it. Usually the main point is the one that has the largest seen area, and the one at which living quarters would be built if the point were manned. The group of points forming a detection station is regarded as one point.

NUMBER OF STATIONS

Experience indicates that seen-area maps should be made for at least twice as many detection stations as will finally be selected for occupancy, and that where decisions as to the relative merits of points are difficult, maps should be made for at least three times that number. Decisions are particularly difficult for large areas where the standard as to percent of area burned annually has been almost or entirely met and it is felt that the unseen portions are larger and more dangerous than they should be. The less the number of detectors allowed per unit of area, the greater is the difficulty of deciding what combination of stations is best.

For a representative area of approximately one million acres largely within the western white pine type, seen-area maps were made from 288 points, of which 178 were fireman stations and 110 were patrol points. Stations selected to be occupied under severe burning conditions numbered 181, of which 112 were fireman stations and 69 were patrol points; in other words, it was planned that 112 men should man 181 points. One point was studied for every 3,200 acres, or every 5 square miles. The plan provides one detector for every 8,320 acres, or every 13 square miles. With all these stations manned, the overlap of seen area would amount to 56 percent of the total.

Influence of Forest Type

General standards for number of potential points to be used in seen-area mapping have been set up on the basis of forest type. It is expected that departure from these standards will often be desirable. Within the general limits of the western white pine type, potential points should average one for every 3,200 acres; within the larch-Douglas fir type, one for every 4,000 acres; and within the ponderosa pine type, one for every 5,000 acres. Existing forest type maps provide a basis for applying these standards. Very little consideration needs to be given to the subalpine type, from either the smokechasing or the detection standpoint, because its needs will usually be satisfied as a byproduct of satisfying the needs of other types.

Influences of Topography and Visibility

The area seen from a single station is largely determined by the shape, depth, and steepness of drainages and the relative scale on which nature constructed them.

As summer drought continues, dust and the smoke of forest fires decrease visibility, and probable rates of spread increase. Detection stations must then be placed closer together to retain the early-season safety in vision distance and to insure quick discoveries. In fire-control planning, a set of stations is first selected to be manned when visibility is average and other sets of stations, spaced less or more widely, are selected to be manned when visibility is less or greater than average.

Allowable vision limits range from 6 to 15 miles.

Influence of Smokechaser Travel Time

It must be kept constantly in mind that each detector is also a smokechaser and must be placed in accordance with fixed limits of travel time to fuels of different kinds. If a distribution of stations that meets detection needs fails to satisfy smokechaser travel-time standards, other stations must be added. Furthermore, since allowable travel time is less when burning conditions are more severe, firemen must be placed closer together as drought conditions continue. Smokechaser travel time requirements must be anticipated from the first, and the seen areas of stations to be added because of them must be taken into account in consid ering potential detection points.

Allowable travel times for initial attack according to severity of burning conditions and fuel conditions are given in tables 11 and 12, on page 66 of Part I.

Influence of Frequency of Fire, Fuels, and Values

Obviously, areas on which the probabilities of serious trouble are high should be better covered than areas low in probable trouble. The areas on which greatest trouble must be expected are those where fires are likely to occur frequently, probable rates of fire spread and resistance to control are high, and damageable values are great. In choosing potential detection stations from which to map seen areas these factors must be known and kept constantly in mind, singly and in combination. Maps indicating the relative status of each of these factors are essential to fire-control planning, and since they will be needed later for that purpose, it is desirable to have them completed and made available to each seen-area mapper before he begins his field work.

Fuel mapping is discussed in Part I, page 49, and instructions for it are given in Part II, pages 89 to 108.

ROAD PATROL STATIONS

It was found in fire-control plan work that construction of a road along a high divide frequently permitted speed of travel sufficient to justify combining into a one-man job the detection duties previously assigned to two or more separately manned stations. Obviously, fewer stations can safely be included in a one-man job when burning conditions are severe than at other times. What combinations are safe under different degrees of burning severity constitutes a problem in planning. On the seen-area mapper falls the responsibility for providing evidence as to coverage obtainable, through use of an automobile as well as by walking, in point-to-point travel and detection observations. Wherever roads seem to offer possibilities of efficient point-to-point detection, points within 5 minutes' walking distance from the roads by trail should be examined. The standard minimum observation time for any point is 15 minutes. Although it is frequently possible to make some observations from a moving automobile, particularly if the observer is not driving, no observations thus made are assumed in planning.

PREPARATIONS FOR FIELD WORK

POTENTIAL-POINTS MAP AND BASE MAPS

Before field work is begun, a "potential-points map" will be prepared. On this map will be shown all points that have been occupied by detectors and all others that are known to be worth examining. Locations for per diem guards should be shown according as such guards can be depended upon and are needed. Later, during field work and in consultation with men well acquainted with different localities, still other points worth investigation will be discovered and added on the map The proposed work of seen-area mapping near the boundaries of adjacent forests should be coordinated with that on the other side of the boundaries, to eliminate duplication and to prevent omission of mapping needed.

Also, before field work is begun an individual base map will be prepared for use at each of the potential detection points. A topographic map will be used if available, otherwise a planimetric map. Around the detection point a circle of 15-mile radius will be drawn on the map with ink. Each seen-area mapper will be provided with such a map for each point assigned to him, and with blank maps that can be used for points added as field work progresses.

WRITTEN INSTRUCTIONS TO MAPPERS

When the potential-points map has been tentatively completed, brief instructions will be prepared for each mapper. These will specify, by name or number, from what points he is to map seen area, under what conditions he is expected to work, and what order of procedure he is to follow. Mappers should carry both the general and specific instructions in their field mapping kits, and should thoroughly familiarize themselves with both.

EQUIPMENT

For satisfactory mapping it is essential that equipment be light and convenient. The items needed are as follows:

Plywood map board, 16" x 16".
Knock-down tripod (Army sketching case).
Open-sight alidade (10"-16" base).
Abney level, percent
Compass (Forest Service standard or equal).
Timber scribe.
Belt ax.
Tree bracket for fastening map board to treetop.
Tree climbers complete with safety belt.
Scale (in chains).
Small protractor.

Stiff-back folder 16" x 16" (for maps and tracing paper).
Profile sheet made on coordinate paper or cellophane.
Tracing cloth or paper.
Notebooks and paper.
Pencils, crayons, erasers, keel, clips, etc.
Heavy letter-size envelopes.
Good-quality field glasses.

The outfit should be packed in a canvas carrying case fitted with pockets and shoulder straps, to be carried on the back.

ORGANIZATION, PERSONNEL, AND TRAINING

For each forest a foreman of seen-area mappers should be selected. This foreman must be qualified to inspect seen-area mapping; that is to say, he must be well qualified to map seen areas with a high degree of accuracy. He should be held responsible for the quality and quantity of work done, and for compliance with whatever instructions apply to the work. He should be relieved of other work to the extent needed for efficiency.

Obviously, a man charged with the responsibility of providing seen-area maps to be used in deciding what combination of fire-detection stations is best should be one familiar with plan work and sufficiently versatile and observing to collect data on local conditions differing from the ordinary.

Before beginning field work mappers who have not previously received special training will be trained in groups not exceeding six men to one instructor. Training conditions will approximate those of regular field work as nearly as possible. Each man will be required to do all the mapping work necessary at one detection point, and to collect the prescribed information as to improvements necessary for occupancy of the point. It is expected that men not adapted to the job will be eliminated in the course of the training period.

FIELD WORK

METHODS OF MAPPING SEEN AREAS

Several methods have been developed for determining the seen area of a detection station. The profile method, which utilizes the data of a contour map, cannot be depended upon unless the map is above average in accuracy, but is useful as a rough guide. Tracings of the outlines of shadows cast by a tiny light placed on different peaks of a relief model have value corresponding to the accuracy of the relief model. The photographic method, utilizing a specially constructed panoramic camera, is adapted to use on a tower or on a point the view from which is not obstructed by trees, where roundness of mountaintop is not a factor. Obviously, it is not suited to mapping from a large number of forest-

covered points many of which will never be improved. The plane-table survey method, used by the Forest Service in the northern Rocky Mountain region, has a higher ratio of accuracy to cost than any other.

Under this method, interference of trees on mountaintops is overcome by climbing the trees and mapping from their tops. Roundness of mountaintop is overcome by setting the plane table at as many places as necessary around the break of the top. The following example illustrates the method of procedure: A distant ridge partially in view over a nearer ridge is identified on the leveled and oriented base map. An alidade is used to locate on the map the points where the distant ridge disappears behind the nearer ridge, and the distant ridge top between these points is indicated on the map, by color, as seen. If a planimetric map is being used, the horizontal distance across the area seen on the distant ridge is estimated and on the map it is colored as seen. On planimetric maps of this region recently made by the Forest Service from aerial photographs, ridge tops are accurately shown by symbol.

If a contour map is being used, the vertical extent of the portion of ridge seen is estimated, or measured, and this portion is identified on the map and colored as seen. Measurement of the vertical distance seen can be made with an Abney level. A device better adapted to constant use with contour maps is a thin transparent profile sheet included in the equipment list on page 112. The field profile method is identical with the office profile method in principle. It should be used constantly during training periods and thereafter until the mapper is able to visualize shapes, widths, and sizes of seen areas viewed from various distances and in different kinds of terrain. The field profile sheet furnishes the mapper with a mechanical means of checking his work and should be used frequently even after he has become proficient in mapping. It is just as important for the mapper to apply checks to his estimates as it is for a timber cruiser occasionally to measure the diameter of a tree as a check on his ocular estimate.

The position of the point from which mapping is done is determined by the tracing-paper solution of the "3-point problem."

Profiles plotted from topographic maps will not be used except where dense timber at round-topped points makes mapping uncertain even with a great deal of tree climbing. They will not be used at any point as the primary method of mapping in any directions except those in which the view is seriously obstructed by trees, and will not be considered satisfactory until checked by observation from, or through, trees.

Care should be taken to assume as the elevation of the observer the observatory height advocated.

Mapping from Treetops

The mappers' most troublesome job will be encountered on heavily timbered points where mapping will have to be done from the tops of trees. To those unfamiliar with it the job looks impossible, yet a considerable amount of mapping by this method has been done with good results. It is not expected that any man hanging in the top of a tree by a safety belt is going to do as expert a job of mapping as if he were working on the ground; but it has been demonstrated that mapping within the required degree of accuracy can be done in this way, and in no other practical way can the necessary information be obtained.

Obviously, a man must be a good climber to do this type of work successfully.

Figure 23 shows a bracket used to attach a map board to a treetop Use of the board and bracket instead of sketching by eye is required.

Mapping Scale and Symbols

Seen area will be shown to a distance of 15 miles from the mapping point. All mapping will be done on base maps having a scale of one-half inch to the mile. Exact location as determined by the 3-point method will be shown by a fine-line cross with a circle around it. Area seen from the mapping point will be shown in solid color, including all area seen from points lying within 5 minutes' walking distance of the main point. Area seen from points lying at greater distances will be shown by hachures, a different color or line direction distinguishing what is added by each point.

ACCURACY AND REFINEMENT OF MAPPING

The quality of the base maps available varies considerably among forests and even among different portions of the same forest. The range of variation is from good topographic maps to poor planimetric maps. Any map that falls below the present Forest Service standards for good planimetric maps is not acceptable as a base for seen-area mapping. If a forest is covered partly by a topographic map and partly by a good planimetric map only, seen-area mappers will be given as much training as possible on the topographically mapped portion.

At a distance of 7 miles from the mapper, it is permissible to leave a 50-acre area undistinguished from the surrounding area as seen or unseen if its boundaries cannot be distinguished definitely. The maximum size allowable for unmapped spots increases with distance from the mapper. At 10 miles it should not exceed 100 acres; at 15 miles such spots must not be larger than 200 acres.

No attempt will be made to classify unseen areas as to whether smoke rising from them would probably come into view of a detector. (The factor of smoke rise was, however, considered in setting the maximum sizes for unmapped spots.)

Although these instructions require the mapping of seen areas to a radius of 15 miles, it has been found that in this region the distance to which vision is reliable averages only 8 to 11 miles. In order to determine reliable-vision limits, and to enable inspectors to allow for them, the following graphic record will be made at half-hour intervals by every mapper at every point from which seen-area mapping is done. As the mapping from any point progresses, the mapper will show, on a radial line just outside the 15-mile limit, the time of day he is mapping each sector. In the same radial direction he will estimate the distance at which he finds it difficult to distinguish unseen spots of 100-acre size, and draw a dashed line on the map at this limit. He will not draw such a line across sectors where vision to the reliable limit is obstructed by topography.

So far as possible, seen area mapping will be scheduled in such a way as to avoid working within 10 degrees of the sun's direction. A desirable procedure is to begin mapping 10 degrees ahead of the sun.

Small areas are invariably to be mapped as unseen if actual doubt of seeing them exists in the mind of the mapper.

In determining differences between areas shown as seen by mappers and areas so shown by inspectors, the locations as well as the acreages of mapped spots must be recognized. It has been found that even when mapper and inspector show nearly the same total acreage of seen area, often they differ greatly as to the location of many areas.

The mapper's "error" is found by totalling the acreages of additions made by the inspector and the acreages of reductions made, and expressing the average of these two sums as a percentage of the area mapped by the inspector. Under most difficult conditions the error should not exceed .5 percent; under ordinary conditions it should not exceed 3 percent.

A rapid and satisfactorily accurate method of measuring the many small areas involved is to scratch carefully a thin transparent sheet with squares of small, known, equal size, and through it count the number of squares lying within mapped areas.

PERPETUATION OF MAPPING STATIONS

It is highly important that fire-control managers be able to identify for firemen the exact spots from which detection observations are expected. Every spot from which mapping is done will be perpetuated by a blaze on a tree or, if no suitable tree exists, on a stake not less than 4 feet long and 2 inches in diameter, set securely in the ground or in a mound of stones. The number of the station unit as shown by the potential-points map will be scribed on the tree or stake of the unit considered to be the main point. On each of the other trees or stakes of the group will be marked plainly, in crayon, the number of the unit and a letter identifying the spot. The relative locations of all observation points of the group will be shown in a diagram on the back of the seen-area map of the station unit.

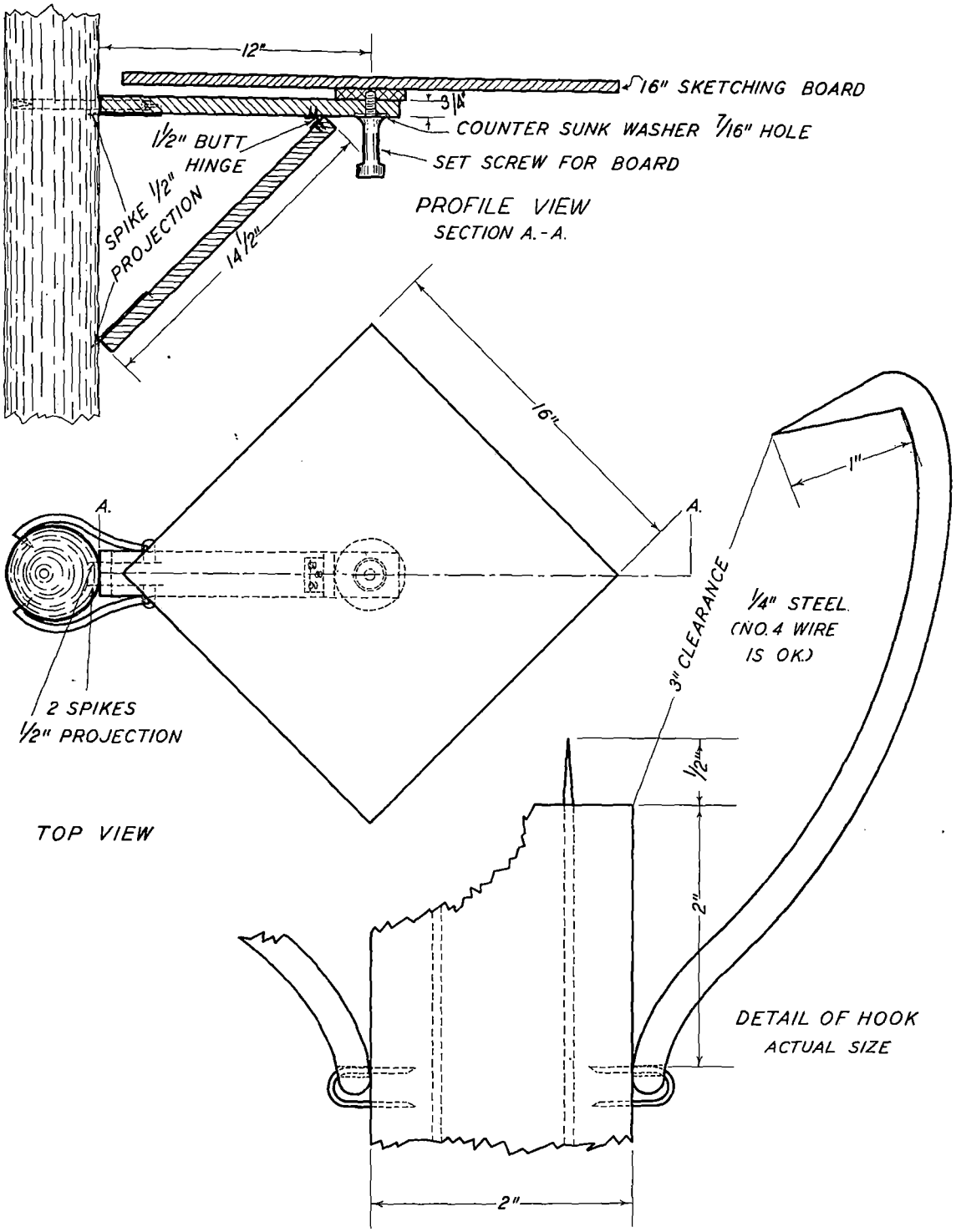


Fig. 23.—Bracket for fastening map board to treetop.

RECORD OF CONDITIONS AT TIME OF MAPPING

Information corresponding to the following example will be recorded on the back of each seen-area map at the time when mapping is completed.

No. 87, Eagle Point
(Number and name of point)

Date August 16, 1932 Mapped by John Doe
Weather Cloudy and windy, threatening rain.
Visibility Local smoke interference in NW quadrant.
Actual mapping time (exclude interruptions) 3-3/4 hours
Remarks At spot A, I mapped from 30 feet up tree. From spot C, profile used in direction S 20° W.

Any difficulties encountered in mapping will be described briefly.

In order to facilitate the transfer of information when seen area maps are used later over glass-topped tables, lighted from beneath, data recorded on the backs of maps will not be placed over any of the areas colored on the face of the map.

PROGRESS MAPS

In order that the work of selecting potential detection points and mapping from them may be systematically planned and scheduled, a progress map will be kept up to date by the officer in charge and by each mapper for the work for which he is responsible. On a tracing-cloth sheet the size of the forest map, the area seen from each point will be entered in solid color as it is mapped. A progress map kept up in this way will show the sizes and locations of areas not yet covered. Seen-area maps prepared in the office by the profile method will not be entered on the progress map until checked by field mapping.

COLLECTION OF IMPROVEMENT-PLAN DATA

The form designed for entry of improvement-plan information is shown on page 120. This form will be reproduced on the blank side of coordinate paper. The coordinate paper is to be used for working out the location and height of the observatory by methods described and illustrated in figure 24.

The time of a mapper on a mountaintop is too valuable to be used for unnecessary purposes. The mapper will collect all the data called for by the form only if he can do so without climbing the mountain a second time for the purpose or causing material delay in mapping progress. Otherwise he should omit the part indicated, which can then be collected at another time by someone else.

FOLLOW-UP WORK AT SITES CHOSEN FOR OCCUPANCY

Check of Observatory Height and Location

After the seen area of each point is transferred to a transparent sheet, and composites showing all the seen area that can be obtained by occupying different combinations of points have been studied over a glass-topped table lighted from beneath, a set of stations will be selected for occupancy. It may then become apparent that at some point under consideration no tower, or a lower tower than that determined by the preceding method, may be satisfactory because one nearby lookout or perhaps two lookouts can see the lower slopes hidden if a tower is not used. In other cases single or duplicate coverage may be possible without a tower if short patrols to secondary points are made. Distances to available patrol points together with frequency of fire occurrence, fuels, and values at stake in the area under consideration have important bearings on the necessary height of tower and the place on the mountaintop that is determined to be the main point, where the combination observatory and living quarters is to be constructed.

At the time of mapping from any potential point, the adjacent points that will be selected cannot be known. For this reason a man familiar with planning procedures and with construction problems should, before construction is undertaken, re-examine conditions at each selected point and make a final decision of tower height and location. In doing this he should carry with him for study a map showing the overlaps of seen area from selected stations, and this map should show which points have been selected for occupancy for the entire fire season and which are to be short-season stations.

Scheduling Patrols for Greatest Efficiency

After the observatory is constructed and trees that interfere with vision have been removed at each point selected for occupancy, the original seen area map of the point should be checked and corrected from the actual location of the lookout map-board.

After this has been done a study should be made to determine what seen area it is desirable to add by the use of patrols (point-to-point detection) to be required of the occupant of the station. Considering the data discussed under the preceding subject, it is obvious that selection of the most efficient set of patrols from any main point is a complex problem involving the seen areas of main stations and patrols that will be obtained from other points covering any particular area. It is necessary not only to cover areas of greatest danger for the largest possible number of hours, but to schedule times of observations so that a dangerous area will not be left uncovered by all detectors at the same time.

Another problem in point-to-point detection, when burning conditions are minimum and where roads have been constructed between stations, involves patrolling by one man to several stations, each of which will be occupied by a detector when burning conditions become severe.

Field Form

IMPROVEMENT-PLAN DATA

ENTRIES DOWN TO HEAVY LINE ARE IMPERATIVE AT EVERY POINT

Point no._____ Name_____ Location _____

Examined by_____ Date_____, 19__.

A. Improvements needed
1. Height of observation platform above ground _____ ft.
2. Sketch shape of hilltop and relative location of observer on back of this sheet.
3. Location of center of observation platform is to be marked on ground by stake securely set, or by scribed tree. Has this been done?_____

B. Shape, etc., of hilltop
1. Is it sharp and rocky?_____
2. " " " " timbered?_____
3. " " rounded and open?_____
4. " " " " timbered?_____
5. Peculiar difficulties of construction at this point _____

C. Timber
1. a. How many trees to be cut to clear for improvements?_____
b. Green or dead?_____ Average diameter_____

2. a. How far to timber suitable for cabin or tower?_____
b. Direction or location_____
c. Average length_____ Av. diam._____ Species_____
d. Green or dead?_____ Standing or down?_____
e. Straight_____ Sound_____
f. Can it be skidded to building site?_____
Easy or difficult chance?_____

D. Water
1. How far?_____ Direction_____
2. Kind of water chance: Spring, how big?_____
Stream, how wide?_____
Bog hole, swamp, or wet spot that can be developed?_____

E. Horse feed
1. How far?_____ Direction_____
2. Size of patch_____ Kind of feed_____
3. How much fence needed to hold stock?_____
4. Is fence material available?_____

F. Other remarks: State any important considerations regarding the use of this point_____

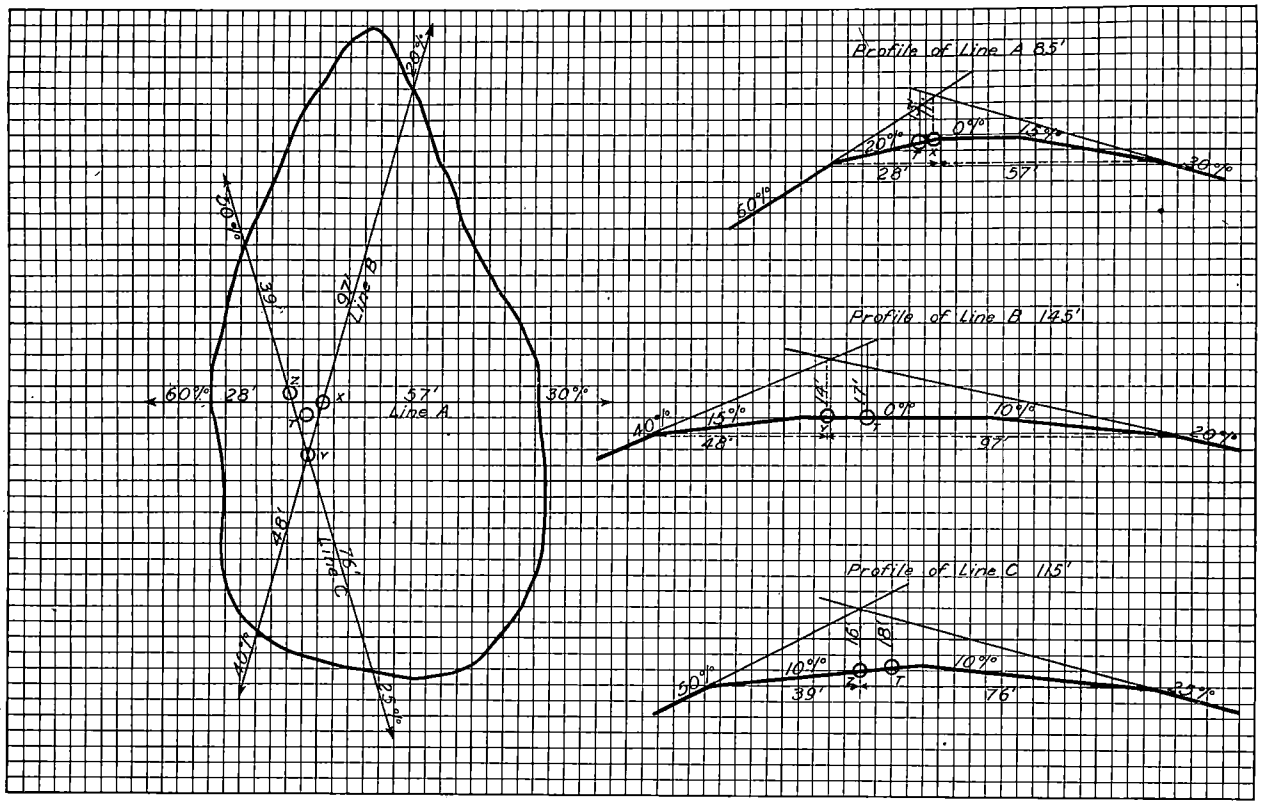


Fig. 24.--Method for determining location and elevation of lookout.

First: Sketch break of slope on scale of 1" to from 25' to 50'.

Second: Select by eye approximate building site, and with series of Abney shots and pacings plat profile across it from steepest point of break in slope (line A). From intersection of two steepest slope lines on profile of line A, drop perpendicular to ground line. This locates point X 28' horizontally from steepest break in slope. At X, eye must be 11' above ground to see over slope in both directions along line A.

Third: Through X select line B in some direction in which it is important for the lookout to have continuous vision, and plat its profile the same as above. This gives point Y as location from which vision is possible in both directions along line B with lowest possible elevation above ground (14').

Fourth: Through Y select another line of sight, C, if necessary to cover some other area which lookout should observe continuously. Plat its profile. This gives point Z with a necessary height of 16' for vision along line C. Proper location for center of tower will be at center of triangle formed by points X, Y, Z. Call this point T.

Fifth: Insert location of T successively in profiles of lines A, B, and C. This gives respective heights above ground of 13', 17', and 18'. Therefore, when eye is 18' above ground at T it can see over break of slope along all three lines of sight A, B, and C. If it is assumed that average lookout's eye is 5' from ground, height of platform in this case would have to be 13'.

Heights of towers are multiples of 10'. Thus a 20-foot tower is indicated here.

A large amount of investigation remains to be done before the relative merits of stationary versus point-to-point detection are determined for different conditions of danger. The question of whether it is better with a given amount of money available to see part of an area all the time or all the area part of the time is being answered annually by many fire control managers and in many different ways, any one of which may be best suited to a given set of conditions.

Special instructions are necessary for seen-area mapping that is done for the purpose of scheduling point-to-point detection. In formulating such instructions it is necessary to recognize that much longer patrols are desirable in certain localities than in others, and special legends are necessary to differentiate complete seen areas from additions obtained patrols of different lengths.

SUPERVISION AND INSPECTION

The officer in charge must give the job sufficient supervision to insure that the work of different mappers is being coordinated correctly and that all information called for by instructions is being obtained and recorded in a satisfactory manner. At least four inspections of each mapper's work should be made during the season. The first inspection should be made within 10 days after the mapper actually starts work. If inspection shows clearly that the mapper is not qualified to do the job, his services as a mapper will be dispensed with immediately. If inspection shows only minor weaknesses that can be corrected, the mapper will be retained and a brief opportunity given him to improve his work. A second inspection of each doubtful man should be made within one week after the first, and a second inspection of all men should be made within two weeks after the first. There must be no hesitancy about dispensing with a mapper as soon as it is definitely known that he is incompetent or unwilling to do the work as required.

Regional inspectors are responsible for checking the work done by local inspectors in the same ways as the work of the field mappers is checked. Inspectors are to record each inspection, and the records are to be preserved. A copy of each record should be given to the man inspected. If possible, inspection should be made in his presence and training of the mapper is to be considered as important as determining the quality and quantity of work performed. A typical inspection report on the standard form is shown on page 123.

RATE AND COST OF SEEN-AREA MAPPING

Other influences on speed than those discussed are time required for travel, and lost time caused by rain and obscurity due to smoke, dust, and clouds. The average time used for mapping from 2127 points was 2.5 days and the cost $9.75 per point. Average costs on different national forests ranged from $7.00 to $12.00.

Field Form

SEEN-AREA MAPPING

INSPECTION DATA REQUIRED

The following will constitute an adequate inspection of the work done at one point:

(1) A check of all improvement information obtained against the checker's judgment of that required.

(2) A check of the quantity of work done in a given time, due consideration being given to weather and travel conditions and to smoke, haze, or other factors that may retard progress. (Under normal conditions, average sketching time per point, for an experienced mapper should not exceed 4 hours.

(3) A check of the quality of work done, made in the following manner:

(a) Do the improvement job separately and compare results.

(b) Check seen-area mapping by an ocular check of entire map; then select a sector of about 10% of the seen area mapped, containing the most difficult topography, and remap it accurately. Remapping will be done on original map. Boundary of inspector's seen areas will be shown by ink or indelible-pencil lines.

(c) Inspectors will date and initial each map inspected and make suitable notes on it. Results will be considered satisfactory if variation between mapper and inspector is not more than 5% of entire seen area where good map is available as base. Where it is necessary to use a low-grade map as base, variation between mapper and inspector must be less than 10%. Where most of the seen area lies within 10 miles of the mapper, differences between mapper and inspector should not exceed half these percentages, under average conditions of mapping difficulty.

Inspection data will be recorded on the form on the reverse side of this page.

SEEN-AREA MAPPING - INSPECTION MEMORANDUM

Forest *Coeur d'Alene* Point No. *94* Name *None*

Mapped by *John Doe* Date *July 1* 193*2*.

Inspected by *Richard Roe* Date *July 12* 193*2*.

Check insp. by *H. R. Smith* Date *July 12* 193*2*.

Inspector's check against mapper. Area within sector checked.		Check inspector's check against mapper ___, inspector ___. Area within sector checked.	
Seen by insp.	*10,600* Acres	Seen by chk. insp.	*9,850* Acres
Added " "	*460* "	Added " " "	*80* "
Deduct. by insp.	*160* "	Deduct." " "	*170* "
Av. of + and -	*310* "	Av. of + and -	*125* "
% of insp.'s S.A.	*2.9* %	% of chk. insp.'s S.A.	*1.3* %

RECORD OF MAPPER'S WORK. Blank spaces to be filled out by inspector.

Reason for difference: *Most of differences lie beyond 10 miles. Along Blue Cr. 130 acres of seen area not shown.*

Is accuracy satisfactory? *Yes* If not, why not? ___

Speed of mapper: Actual time used mapping seen area *5* hrs.
Was time satisfactory in relation to accuracy *Yes. Choppy topography to west is difficult.*

Visible limit line: Does it appear satisfactory? *Yes. Hour of mapping sectors not shown.*

Comments of check inspector on accuracy *Except strip along Blue Cr., accuracy very good.*

BUILDING-PLAN DATA: Complete? *Yes* Satisfactory? *Yes*
Remarks *Tower advocated not essential since short patrol along brink of bluff necessary anyway.*

GENERAL: Is proposed-points map kept posted currently? *Yes.*
Is composite progress map posted currently? *Yes.*
Other remarks *Industrious and plans his work well.*

CONCLUSIONS: Is employee OK for this job? *Yes.* Why? *Great improvement over previous inspection. Inexperience overcome.*

DETAILS OF TRANSPORTATION PLANNING

In topography such as that in much of the northern Rocky Mountains road routes frequently are most direct and construction costs least in broad valleys and on or near the tops of major and secondary divides or long ridges. Roads in the latter places have the added advantage of permitting down-hill walking from roads to fires. These facts are so obvious one is tempted to argue that nature has already planned the logical road routes. However, the highest costs of construction are frequently encountered in getting onto and off of divides. Furthermore, the needs of fire control are not satisfied merely by constructing roads in the least expensive places. Apathy toward systematically planning fire control roads is rarely encountered among men who have gone onto the rugged and large slopes intermediate between ridge tops and valley bottoms and tried to answer the question, how can we get men to this particular spot of fuel soon enough to give them a chance to extinguish a fire faster than it will spread? Studies of the very limited degree to which travel-time standards are satisfied in large areas, the rapidly mounting annual expense of road maintenance, and the difficulty of getting it done, give strong evidence of the need for very thorough planning.

Transportation planning involves primarily delivering to any spot the number of men needed. Under certain conditions, varying with intensity of burning severity, number of men (rate of work) can compensate for slowness of travel. The principal considerations involved are allowable travel time (dependent upon fuels and burning severity), rate of travel, location of man power, and number of men per station. Since the roads and man power needed when burning conditions are worst are more than enough at other times, the work of planning for less severe conditions involves partial use of the maximum required developments and man power. In planning three services of action are involved, smokechasing (initial attack), light reinforcements (small crew action), and heavy reinforcements (large crew action, or heavy second line defense). Because direct trunk routes are essential to heavy reinforcement action, that service is considered first.

HEAVY REINFORCEMENTS (HEAVY SECOND LINE DEFENSE)

On pages 49 and 61 of Part I road planning for heavy reinforcement action is discussed in detail sufficient to give a general knowledge of the methods used. This work requires the services of an engineer experienced in road construction and maintenance, and since standard civil engineering practices are involved, discussion of them is omitted here.

Heavy reinforcement action means delivering 100 or more men to any spot by daylight. The time available for actual travel is specified as 8.5 hours from the only cities that can supply 100 men to the western forests of the region on short notice, Lewiston, Spokane, Missoula, Butte, and Great Falls.

The rates of travel applied in planning to the movement of these large crews during the night are; on roads, the rated speeds of particular portions; on trails, 1.5 miles per hour; and off trails, 0.5 mile per hour.

Studies of performance indicate that busses are slightly faster than trucks on main highways, but somewhat slower on forest roads. The average speeds of these vehicles were applied to the use of either one. The road speeds used were determined for main highways by commercial bus schedules and experience with Forest Service trucks, and for forest roads by tests of several types of loaded trucks over 115 miles of representative roads on the Coeur d'Alene and Clearwater forests. Speeds on other roads were based on comparisons. After excluding the poorest road (having a speed of 6 miles per hour) the average speeds were found to vary from 8.2 to 18.6 miles per hour, the weighted average being 11.8. For similar roads a speed of 10 miles per hour was used in plan work.

In determining coverage a sheet of tracing paper is placed over the forest map and an 8.5-hour time contour from each man power center is worked out, based on the existing road system. Another time contour 4 hours further is worked out to show the limit reachable by approximately 10 o'clock, a.m. On another tracing similar contours are worked out showing the limits reached by use of the proposed road and trail system. The second tracing is made after possible road routes have been investigated and those roads proposed that extend the coverage into areas shown on the first tracing as not reached. Partial tracings are used to show alternative possibilities.

In determining the distances, in horizontal projection on the map, reached by foot travel dividers are used, being set to allow for slope and indirect travel according to local conditions of topography and travel obstructions.

LIGHT REINFORCEMENTS (SMALL CREW ACTION)

The necessity for providing a light reinforcement service is discussed on page 81. Methods of planning to satisfy this need are discussed in general on page 62. Knowledge of these data are assumed here.

Small crew action contemplates the use to the distance possible of man power available in communities. Beyond the limits reachable by such crews, the existence of hired crews located to best advantage in relation to the road system is assumed.

Airplane landing fields constitute an important part of this service. In planning for them and in determining coverage from them, the time required for assembly of men and delivering them to each field from Spokane and Missoula was determined and subtracted from the allowable

travel time. It is estimated that 20 men can be delivered to any landing field west of the Continental Divide before dark.

The travel time limits are based on controlling a 50-acre fire before 10 o'clock of the morning following spread of the fire. These limits, according to crew size and resistance of the fuel to control, are shown by table 9 on page 62.

METHOD OF WORKING OUT LIGHT REINFORCEMENT COVERAGE

On a forest map are shown the number of men available at different points and the number of hours required for assembling them. The assembly time is subtracted from the travel time shown in table 9 for each fuel resistance. The distance in terms of time to which each fuel can be covered is thus determined.

Time contours in different symbols are used, one for each class of fuel resistance. Using a sheet of tracing paper the size of the one-half inch to the mile forest map, and beginning at the point of assembly, the first contour is placed at the distance to which fuels of extreme resistance can be reached by travelling existing roads and trails, From this contour the additional distance to which fuels of high resistance can be reached is determined. The remaining contours for medium and low resistance fuels are determined in the same way. This tracing is then placed over the fuel map. By inspection the fuels of extreme resistance that lie outside the first contour are identified and drawn in symbol on the tracing. Similarly the fuels of high and medium resistance lying outside their respective contours are identified and shown in their respective symbols on the tracing. Some of these uncovered fuels will be reached within contours worked out from other starting points, and when so covered they are erased from the tracing. In this manner the fuels covered and not covered from all communities are determined.

Beyond the limits reachable from communities, sizes and locations of crews are assumed that appear best according to size of area to be covered and the fuels left uncovered are identified in the same manner as just described.

After determining coverages possible by travelling the existing road and trail system, road and trail extensions are made and proposed landing fields are shown and the added coverages determined. After completing the composite coverage tracing, it is necessary to reconsider the first decisions and for parts of the forest to work out on partial tracings amended and alternative plans for completing coverage to the desired degree.

Where the time contours of adjacent crews meet a division line of responsibility is shown, and thus the area of each crew's responsibility is defined.

The speeds of travel assumed for small crews are somewhat faster than those used for 100-man, heavy reinforcement crews. Small crews are moved by passenger cars or light trucks about 5 miles per hour faster; foot travel on trails is about the same, 1.5 miles per hour, but walking off trails is assumed to be at the rate of 0.75 to 1.0 mile per hour, since local men accustomed to such travel will usually be the type used.

METHOD OF DETERMINING ALLOWABLE TRAVEL TIMES (NIGHT REINFORCEMENTS)

Although the starting time of action was assumed to be 5:00 p.m., studies of experience showed that about one hour must be allowed for lost motion caused by delays in getting started and for failures to follow the most direct routes. For this reason 6:00 p.m. was used as the probable time of starting action. From 6:00 p.m. to the next 10:00 a.m. is 16 hours, during which the jobs of travel and control are to be performed. By adding the work that can be accomplished by a crew of particular size in the 16th hour to that of the 15th, and earlier hours, one can determine the number of hours before 10:00 a.m. required at a fire of particular size to control it, and the time remaining (out of 16 hours) can be utilized for travel and assembling men.

Based on the idea just presented, figure 25 shows the graphical method employed. Chart A shows the estimated influence of crew size on the average rate of work per man per hour. The curve is based on meager statistical data supplemented by a large number of estimates made by experienced men. The following influences were recognized:

1. Size of fire, when larger than can be controlled by 5 men, prevents the men from working back and forth across or around the fire and assisting each other in removal of logs, attacking hot spots, and prevents interchange of tools.

2. The best trained men are utilized on the smallest sizes of fire, and the quality of personnel decreases with crew size.

3. The percentage of time necessarily subtracted from labor for supervision increases with crew size.

In charts B, C, D, and E the vertical spacings of curves for different sizes of crews are determined by the values shown in chart A.

The influence of fatigue estimated by experienced men is shown by charts B, C, D, and E. Attention is directed to the fact that night work is under consideration. It is assumed (satisfactorily for the purpose) that riding in trucks, walking, and working on a fire are equally fatiguing. It will be observed that after reductions have been made through 10 hours of time after 6:00 p.m., no reduction is made from 4:00 a.m. to 7:00 a.m. This is due to the increase in daylight, permitting more effective work and offsetting increased fatigue.

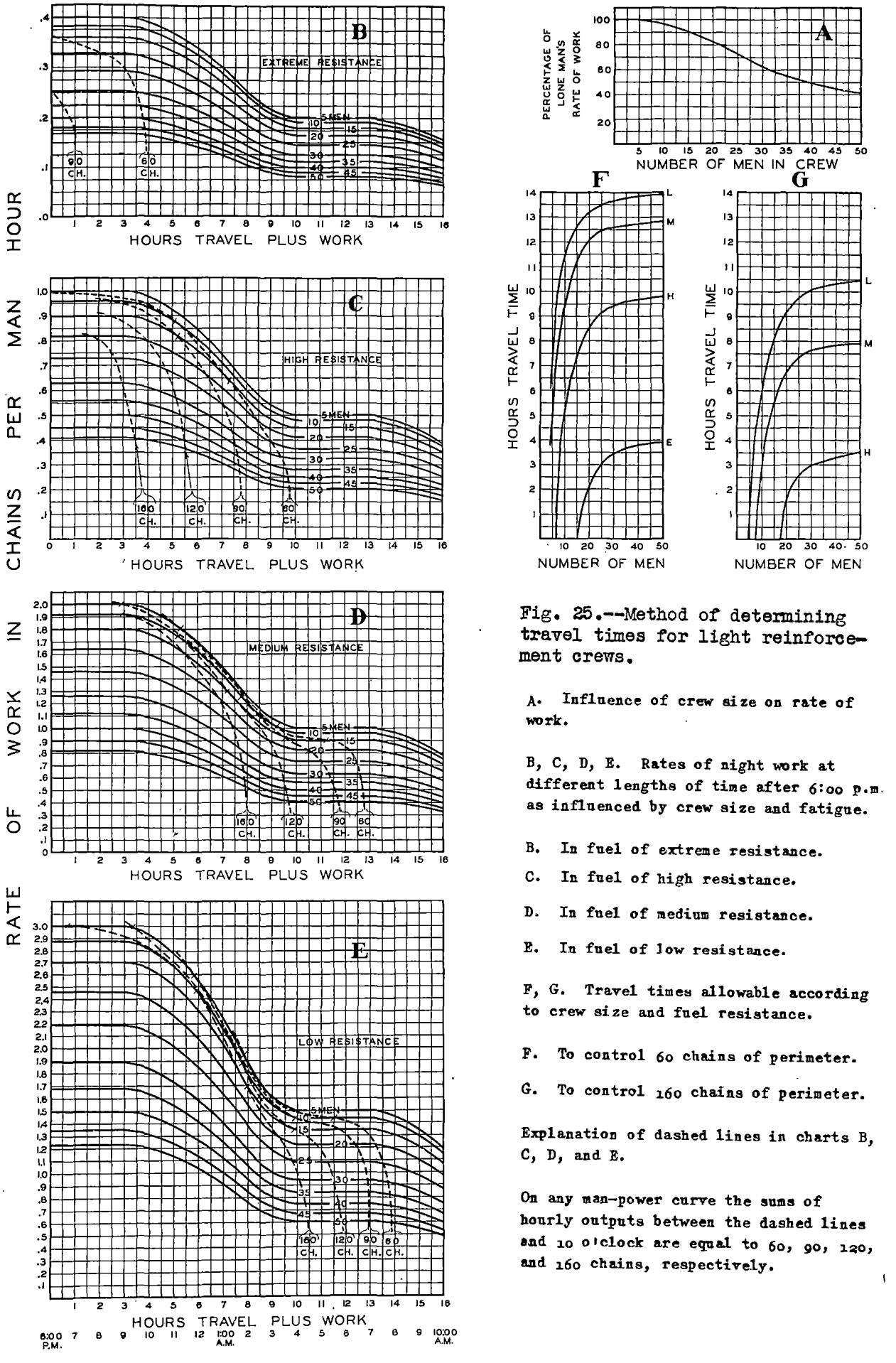


Fig. 25.--Method of determining travel times for light reinforcement crews.

A. Influence of crew size on rate of work.

B, C, D, E. Rates of night work at different lengths of time after 6:00 p.m. as influenced by crew size and fatigue.

B. In fuel of extreme resistance.

C. In fuel of high resistance.

D. In fuel of medium resistance.

E. In fuel of low resistance.

F, G. Travel times allowable according to crew size and fuel resistance.

F. To control 60 chains of perimeter.

G. To control 160 chains of perimeter.

Explanation of dashed lines in charts B, C, D, and E.

On any man-power curve the sums of hourly outputs between the dashed lines and 10 o'clock are equal to 60, 90, 120, and 160 chains, respectively.

The dashed lines in charts B, C, D, and E cross each curve at a point such that in the remaining hours 60, 90, 120, and 160 chains of fire perimeter can be worked by the size of crew indicated, if the output of each man in each hour is that indicated by the vertical scale. The intersection points show on the horizontal scale the time that can be used for travel plus that for assembling the crew. These times in relation to number of men per crew are plotted in chart F for control of 60 chains of perimeter and in chart G for control of 160 chains.

The probable perimeter of a 50-acre fire is 120 chains; three-fourths of it is 90 chains, and one-half is 60 chains. For a very irregular perimeter the length may be as much as one-third greater, or a total of 160 chains. Another consideration necessary here is that only three-fourths of the perimeter of the average fire requires control work. Since the fire may be very irregular in shape, the control of 160 chains may be necessary with the unusual fires that remain active throughout the night. The curves of chart G show according to crew size the travel times that can be used. Or, they can be used by dispatchers as guides to the number of men that should be sent when a 50-acre fire is at different distances (in time) from them, providing that the crew accomplishes the rates of work assumed. In table 19 the number of men needed for any size of fire is shown. Attention is directed to the fact that the smaller crews were assumed, in working out these data, to be much more efficient than the larger ones. The sharp bends (changes of slope) in the curves of charts F and G show the combined influences of quality of man power and fatigue.

Anyone experienced in fire suppression probably will be surprised to observe in chart G and table 19 that 20 men are shown to be sufficient (with short travel time) for control of 50-acre fires in fuels of high resistance to control. The essential consideration is that rate of work, and not merely number of men, must be estimated in dispatching. The rate assumed here may be too high to include felling enough snags to prevent escape of fires during the next afternoon unless other crews are sent.

In chart F are shown the travel times that could be used, according to crew size, to control 60 chains of perimeter (half the average perimeter of 50-acre fires). These are the travel times used in planning the placement of small reinforcement crews. Obviously, one crew working alone is insufficient to do the job to be expected. The assistance of neighboring crews was planned. The number of men involved in action, then, is that of several crews, and the travel time is an average.

It was necessary to "try out" the standards in order to find out how close together crews would be after the travel times of chart F are satisfied. This study and later plan work shows that even these travel times require a great many more men to be available per square mile than have ever been contemplated in the past. In localities without roads, or with few roads, it is extremely difficult to satisfy these specifications. The assumption that several small crews will be used for night

Table 19.--*Number of men needed in night reinforcement action to control inactive fires of different sizes before 10 o'clock of the next forenoon.*

Time 6:00 p.m. to arrival	Hrs.	Fuel resistance 2/	Number of men needed 1/ according to size of fire									
			5 acres	10 acres	15 acres	20 acres	25 acres	30 acres	35 acres	40 acres	45 acres	50 acres
7:00 p.m.	1	E	14	30	54	90						
		H	5	8	10	12	13	14	15	16	17	19
		M				5	6	7	7	8	8	9
		L						5	5	5	5	6
8:00	2	E	16	40	70							
		H	6	9	11	13	14	16	17	19	21	23
		M				6	7	8	8	9	9	10
		L						5	5	6	6	7
9:00	3	E	18	50								
		H	7	10	12	14	16	18	21	24	27	30
		M			5	7	8	9	9	10	10	11
		L					5	6	6	7	7	7
10:00	4	E	23	60								
		H	7	11	14	16	18	21	26	35	48	60
		M		5	6	8	9	10	11	11	12	13
		L				5	5	6	7	7	8	8
11:00	5	E	35	70								
		H	9	13	16	20	24	30	48	70		
		M		6	7	8	10	11	12	13	14	15
		L		5	5	6	6	7	8	8	9	9
12:00	6	E										
		H	10	15	20	27	41	57				
		M	5	7	8	10	11	13	14	15	16	18
		L		5	6	6	7	8	8	9	10	11
1:00 a.m.	7	E										
		H	12	18	27	54						
		M	6	8	10	11	13	15	17	19	21	23
		L	5	6	7	8	8	9	10	11	12	13
2:00	8	E										
		H	14	23	60							
		M	8	9	11	13	16	18	21	24	29	35
		L	6	7	8	9	10	11	12	13	14	15
3:00	9	E										
		H	19	50								
		M	9	11	14	17	21	25	32	55		
		L	6	8	9	11	12	13	15	16	18	20
4:00	10	E										
		H	22	60								
		M	11	14	18	23	30	60				
		L	7	9	11	13	15	17	19	21	24	30

1/ These data are based on the rates of work shown in figure 25. For aggressive fires increase the number of men shown. Trained men not seriously fatigued are assumed. Double the number shown if only half the output is expected. Add half if two-thirds is expected. Further reinforcements may be necessary to hold the fire.

2/ E = Extreme, H = High, M = Medium, L = Low.

attack on one fire, makes it necessary for planners to study the crew man power per unit of area as well as the locations of particular crews. The chance exists that each of several fires within a locality will require crew action at the same time. However, as shown by figure 17, A, on page 64, this probability is remote, since only 7 percent of all fires become larger than 50 acres.

In planning no travel times longer than 10 hours are used. This specification is made in recognition of the possible pick-up in burning conditions that not infrequently occurs and increases during the forenoon.

INITIAL ATTACK (SMOKECHASER ACTION)

Methods of working out individual silhouettes of coverage from fireman stations and fitting them together into composites are discussed on page 71. The travel times used in working out silhouettes are shown by table 11 on page 66.

Roads needed for initial attack are considered after those needed for heavy and light reinforcement actions have been determined in the order described. It should be pointed out that the proposed roads planned for reinforcement action are assumed to exist before extensions are made to satisfy the travel-time standards of initial attack. Existing smokechaser coverage is worked out, based on the roads and trails existing on the date the study is made. Unless extremely expensive construction is involved, a connection to the road system is planned for every fireman (except in wilderness areas) and road and trail extensions are planned into areas of worst fuels.

CURRENT ACTION ACCORDING TO SIZE AND AGGRESSIVENESS OF FIRE

RELATIONS BETWEEN TRAVEL TIME, MAN POWER AND FUEL

Dispatchers find it necessary continually to estimate the number of men that should be sent to fires of various sizes, and rates of spread, located in different fuels, at different distances from man power stations, and occurring under different degrees of burning severity. Placement plans provide only for meeting the conditions within certain steps of expansion and contraction of preparedness, and within steps adjustments are left for current determination. However, before selecting the specifications to be used in planning, analyses of speeds and strengths of attack believed to be needed under every degree of burning severity were made. In addition to their current application to dispatching these data are necessary to show the number of men needed per station under different degrees of burning severity and as guides to the temporary placement of man power in lieu of roads, pending completion of the planned road system.

In determining the number of men needed for control two very different conditions of fire aggressiveness are involved; night behavior, when fires usually do not spread appreciably; and behavior during midday burning periods, when if control is not established quickly while the fire is actively increasing in size, it probably will not be effected until many hours later when night influences prevail.

NIGHT ATTACKS

The number of men needed in night attacks, according to size of fire and fuel resistance, after different lengths of time have been used for assembling men and travelling after 6:00 p.m. are shown by table 19. The considerations to be recognized in application of these data are discussed on pages 128-130. Until accurate data are collected on rates of work involved in figure 25, no better estimate of the number of men needed can be made. The data used are the best available, and none of the factors can be left out of consideration. These factors are; fuel (the material in which firefighters work), aggressiveness of fire, training of men, influence of crew size, and fatigue.

MIDDAY ATTACKS

It is necessary to focus attention on midday control of aggressive fires. They occur in every locality and measures of preparedness that will stop them at small size will be more than sufficient for all other fires. Efficient detection is a necessity, that is, such fires must be discovered almost as soon as they begin to spread. In the normal growth of such fires a stage is reached when heat or speed of advance, or both, make it impossible for men to work directly in front of them. Although attack from the rear may be the only feasible method, there can be no assurance that the front will not be miles away before it is reached. The elapsed time limit between discovery and impossibility of work on the front is the outstanding consideration in control of such fires. For the sake of brevity in discussion, this elapsed over-all control time is called "C" and the part of it from discovery until attack is begun is called "a." The difference "f" is used for firefighting.

Obviously, for a particular fuel the allowable "C" time varies with severity of burning conditions, that is, it varies with rate of spread. Under a particular degree of burning severity existing in a locality, the allowable "C" time varies with the rate of spread in different fuels. No field studies of allowable "C" time have been made. However, the correspondence between it and Danger Meter ratings is indirectly available through correlations with rates of spread in different fuels under different ratings of the Danger Meter.

If each smokechaser could be imbued with the feeling of a race between himself and the rate of spread, the goal being the "C" time limit, more fires might be controlled within the first work period and without reinforcement action. Enthusiasm for this race is dampened considerably by the fact that the smokechaser always wins in about 75 percent of the cases, but not when rates of spread exceed 12 chains of perimeter increase per hour. In such cases 83 percent of fires in 1921-30 were attacked within 1 hour after discovery if control within the first work period was accomplished; 98 percent were attacked within 1 hour if rate of spread exceeded 20 chains per hour. These data apply to any kind of fuel and are amply supported by a thorough analysis of 8,789 fires (all for which rates of spread could be determined). Although the average smokechaser of the year 1937 may be better equipped with "guts", asbestos hide, and training to work on hot fronts than those of 1921-30, evidence does not point in that direction. However, more men are now being used in initial attacks on such fires than formerly, thus speeding up the rate of work and shortening the firefighting time, "f." These data must be regarded as good indications of necessary arrival time "a" after discovery of fast-spreading fires. These and other data indicate that the "C" time limit under probable conditions of attack can be about 2.0 hours when rate of spread is 20 chains per hour.

The allowable "C" time when rates of spread are only 3-5 chains per hour appears from analyses to be about 6 hours. A high percentage of fires was satisfactorily controlled in 1921-30 when attack began in 4-5 hours after discovery. When prevailing burning conditions are at this low degree of severity, the critical midday burning period is not longer than 4 hours during which attackers are threatened with the impossibility of working directly on fire-fronts. For this reason "C" times longer than 7 hours are not worth consideration, since they involve work outside the critical midday period.

In figure 26 the over-all control time after discovery, called "C", believed to correspond with each rate of spread, is shown by chart A. Assuming the rate of spread to be that in the average of all fuels, the correspondence believed to exist between average rate of spread and ratings given by Gisborne's Danger Meter is shown in figure 28.

Within the allowable "C" time the operations that must be included are, in order of performance, report-get-away, travel, and firefighting. Report-get-away time is assumed to be constant and require 15 minutes. Since firefighting time can be shortened by increasing the rate of work, the travel time can be lengthened by sending more men, using a bulldozer, a pump, or chemicals. Unless the efficiency of men is known, numbers of them do not indicate a particular rate of work. Rate of work by any means is the essential consideration.

Allowable travel time in relation to different rates of work can be determined for each of the multitude of combinations of factors involved. In setting out to do this laborious job the work can be simplified and systematized by first using letters to represent each of the factors and thereby determining their natural interrelation and obtaining a correct pattern for computations.

DERIVATION OF TRAVEL TIME FORMULA (MIDDAY ATTACKS)

Discovery of the fire at very small size, when it first begins to spread, is assumed regardless of time elapsed since ignition. The elapsed time from discovery to actual control, that is safe to permit, is called "C."

Let C = time from discovery to control
Let a = time from discovery until attack is begun.
Let f = time spent in firefighting. Then f = C - a.

Until attack is begun the length of perimeter, hence the job to be done, increases.

Let p = average rate of perimeter increase during this time, a.
Then ap = the perimeter when attack is begun.

Even in active fires not more than half of the perimeter requires immediate action. Since the other half can be worked later, it is excluded from the work that must be done within the control time, C.

The job to be done = $0.5ap$

Let W = rate of work, that is, (hour) length of perimeter controlled per unit of time that will accomplish control satisfactorily.
Then a rate of work, W, applied for f hours completes the job.
The job done = Wf, or since f = C - a.
" " " = W(C - a) = WC - Wa

Since the job to be done and the job done are the same,

$0.5ap = WC - Wa$. Add Wa to each member.

$Wa + 0.5ap = WC$

$a(W + 0.5p) = WC$

$a = WC \div (W + 0.5p)$ This is the required length of arrival time after discovery.

Let 0.25 hour = allowance for report and get-away.
" t = travel time, the desired and unknown quantity.
$t = a - 0.25$
Therefore $t = WC \div (W + 0.5p) - 0.25$ hour.

Computations of allowable travel time are most simply made by neglecting the 0.25 hour report-get-away time and subtracting it from each arrival time, a, after the computations have been made.

For the sake of simplicity in deriving the formula it was assumed that one-half the perimeter existing at the time attack is begun requires action within the time limit "C." Actually the percentage varies with rate of spread and an estimate of it for any rate of spread is shown in figure 26, B.

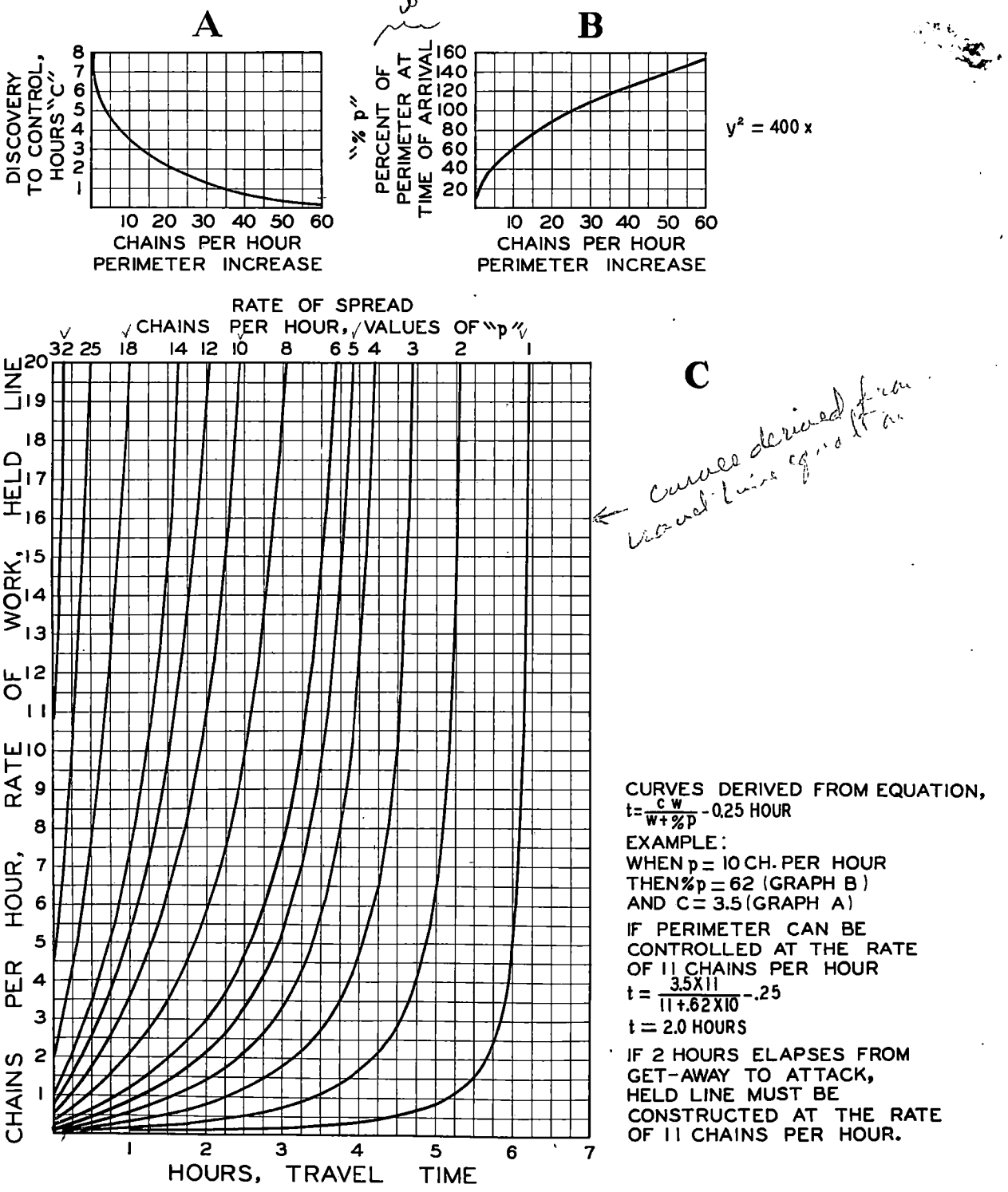

A
DISCOVERY TO CONTROL, HOURS "C"
8 7 6 5 4 3 2
10 20 30 40 50 60
CHAINS PER HOUR PERIMETER INCREASE
B
"% p" PERCENT OF PERIMETER AT TIME OF ARRIVAL
160 140 120 100 80 60 40 20
10 20 30 40 50 60
CHAINS PER HOUR PERIMETER INCREASE
$y^2 = 400x$
C
RATE OF SPREAD
CHAINS PER HOUR, VALUES OF "p"
32 25 18 14 12 10 8 6 5 4 3 2 1
CHAINS PER HOUR, RATE OF WORK, HELD LINE
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7
HOURS, TRAVEL TIME
CURVES DERIVED FROM EQUATION,
$t = \frac{c\,w}{w + \%p} - 0.25$ HOUR
EXAMPLE:
WHEN p = 10 CH. PER HOUR
THEN %p = 62 (GRAPH B)
AND C = 3.5 (GRAPH A)
IF PERIMETER CAN BE CONTROLLED AT THE RATE OF 11 CHAINS PER HOUR
$t = \frac{3.5 \times 11}{11 + .62 \times 10} - .25$
t = 2.0 HOURS
IF 2 HOURS ELAPSES FROM GET-AWAY TO ATTACK, HELD LINE MUST BE CONSTRUCTED AT THE RATE OF 11 CHAINS PER HOUR.

Fig. 26.--Rate of work and corresponding travel time limits required to control fires of indicated rates of spread.

The general form of the travel time formula is

$$t = \frac{CW}{W + \%p} - 0.25 \text{ hour}$$

In figure 26, B, a curve is plotted which is believed to approximate the average percentage of the perimeter, at the time attack is begun, that must be fought within the "C" time limit. It should be noted that "p," used in the equation, is rate of perimeter increase and not the perimeter itself. However, the same result is achieved by application of this percentage to the rate of spread. Attention is directed to percentages greater than 100 shown by the curve. These mean that the fire by advancing during the firefighting time produces a larger perimeter than that found on arrival.

Anyone experienced in making initial attacks on fires and familiar with analytical geometry will recognize that this percentage is 0 when rate of spread is 0 and that the curve must be tangent to the vertical axis at the point 0, 0. From the origin point the curve must rise at a continually decreasing rate, but never stop rising. This description not only suggests the probability that a parabola interprets the relationship, but makes it almost obligatory to use one in the absence of contradictory evidence. It is not presumed that the particular parabola used is the one that field investigations will find to be correct. That is too much to expect of an estimate, even though it is based on the combined opinions of experienced men. Another reason for using a mathematical curve, if one that interprets the data is known, is to prevent the error of placing some sections of the curve at altitudes that are inconsistent with the remainder of altitudes.

APPLICATION OF TRAVEL TIME FORMULA

In making current plans and in taking action on fires two very different methods of approaching the critical issue of midday control are available. One is the "trial and error" method followed everywhere during the past thirty years. The other method is to examine the requirements of the critical issue and decide to what extent these requirements can be met and to what extent it is economical to meet them. In other words, first, what speed and strength of attack is required to control, at small size, the percentage of all fires that cause most of the burned area and damage? Then, to what extent does it appear to be physically possible with ordinary man-power methods to do the job built up by fast-spreading fires? In relation to the time and energy that has been expended in conferences and making elaborate judgment estimates, it does not appear unreasonable to examine critically and in detail the statement of the case presented in summary by the travel time formula and the implications contained in it.

In figure 26, C, curves corresponding to different rates of fire spread are shown. Each of these curves was worked out by the travel time formula, using a particular rate of spread, different rates of work, and the applicable "C" and "p" values shown by graphs A and B. Each curve

shows the travel time that can be allowed if any particular rate of work is applied in attack. With the exception of 15 minutes allowed for report-get-away, the time is that from efficient discovery until attack is begun. The rate of work that corresponds to any point on a curve is that which results from aggressiveness of the fire.

The required rate of extinguishment is entirely free from any consideration of how it is to be done. The set of curves simply constitutes a statement of what different degrees of fire aggressiveness require. After studying them one might be able to decide whether or not he desires to provide the rate of work required. For instance, for the 19 percent of all fires (shown by figure 17, B) that must be expected to have perimeter increases of 18 chains per hour or more, is it more economical to provide everywhere and within 1 hour after discovery, a midday work-rate of 20 chains of held line per hour, or after providing a smokechasing service that will catch most of the fires, to accept the probable burned area and make a strong attack in the evening? One might decide that the highly expensive preparedness required to do the former is justified, where high danger (threat to values) exists. Where resistance to control is low, as with grass fires, it is not difficult in the vicinity of communities to provide a work-rate of 20 chains per hour. Bulldozers, horse-drawn plows, or water may be made available within 1 hour to speed up an otherwise slow man-power rate of work. But even for these light fuels in uninhabited localities with topography such as that found on the 2,000-foot breaks of the Salmon River, providing anywhere near this rate of work everywhere is not simply a problem of justification; practically, it is a physical impossibility.

If man power, using ordinary hand tools, must be relied upon to accomplish the required work-rate, figure 27 shows the number of men required. In this figure the curves of figure 26 are reproduced, and a horizontal set of curves is superimposed on them, showing numbers of men estimated to be required to accomplish the rates of work indicated on the left-hand vertical scale. In the four right-hand vertical columns, the numbers of men according to fuel resistance are shown. The four classes of resistance are the same as those used in the field in mapping fuels, extreme, high, medium, and low.

Figure 27 shows, by curves and interpolation between them, for any rate of spread and any resistance to control the number of men that can be allowed to use any particular length of travel time. For instance, if the men are stationed 1 hour distant from a fire that spread at the rate of 10 chains per hour, follow up the 1 hour vertical line to the dashed curve labelled 10 (at the top of the sheet). At this point a horizontal curve will be found, which if followed to the right, shows that in fuels of low resistance 2 men are required; in medium resistance, 2 men; in high, 5 men; and in extreme resistance, 35 men. For any other travel time the procedure is the same.

If the rate of work that will be applied is known, the horizontal curves and the right-hand data on resistance should be disregarded entirely and the left-hand vertical scale in relation to the rate of spread curves used. Since, in this case, the data are the same as those shown by figure 26, that figure, being more simple, should be used.

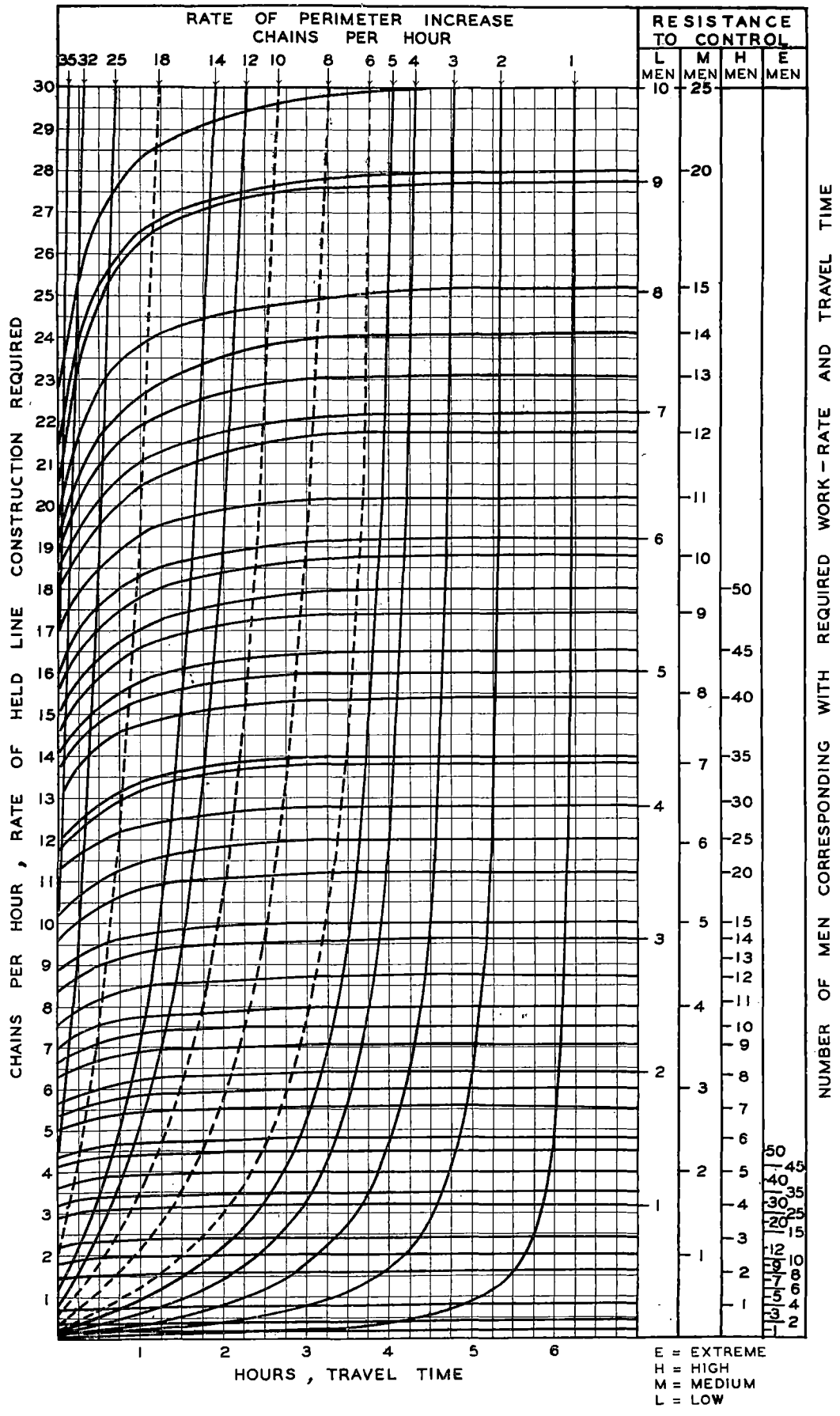

RATE OF PERIMETER INCREASE
CHAINS PER HOUR
35 32 25 18 14 12 10 8 6 5 4 3 2 1
RESISTANCE TO CONTROL
L MEN
M MEN
H MEN
E MEN
CHAINS PER HOUR, RATE OF HELD LINE CONSTRUCTION REQUIRED
HOURS, TRAVEL TIME
NUMBER OF MEN CORRESPONDING WITH REQUIRED WORK-RATE AND TRAVEL TIME
E = EXTREME
H = HIGH
M = MEDIUM
L = LOW

Fig. 27.-- Number of men and corresponding travel time limits required to control fires of indicated rates of spread and resistances to control.

In determining the number of men according to fuel resistance it was necessary to use certain rates of work believed to be applicable. The rates used are shown by the vertical scale of figure 28, B, where they are labelled L, M, H, and E for low, medium, high, and extreme resistances,, respectively. The range of rates shown is based on 1,264 estimates obtained from 25 experienced men covering small crew midday attacks on fires in a wide variety of fuels. After discarding an additional 31 erratic estimates on both ends of the range, the variation shown by the remainder of estimates was found to have a range from 0.2 to 3.8 chains per man hour. This range was divided into three equal parts whose mid-points are; low resistance, 3.2; medium, 2.0; and high, 0.8. The least rate of work, which included a large number of cases, was 0.2 chains per man hour, and this rate was assigned to extreme resistance to control. The rates of work thus obtained are optimistic, that is, support for them cannot be found in fire reports except by selecting the higher rates accomplished.

The curves of figure 28, B, show the way in which rate of work is estimated to decrease as rate of spread increases. Stopping the front half of fires is under consideration. When rate of spread is as great as 50 chains per hour, it is doubtful that appreciable progress is made against the front half of any fire, except possibly in pure grass were resistance to control is very low. Whether the speed, at which the rate of work breaks off abruptly to zero, is 50 or 60 chains per hour is unimportant; the latter is used in figure 28, B. When rate of spread is as low as 3 chains per hour, it has no influence on rate of work, but at progressively faster rates, by advancing here and there along the front and becoming hotter and hotter, and spotting ahead, the rate of work becomes less and less effective and finally breaks off abruptly when the fire, personified, refuses to stay in one place long enough to be fought by any number of men.

The description just given, if true, requires the use of a curve closely approximating an ellipse to interpret the relationship. The curve must be tangent to a horizontal line at the vertical axis, and it must be perpendicular to the horizontal axis at 60. It must drop from its highest position at an increasingly rapid rate. The curves of figure 28, B, are ellipses and their general equation is given. For any set of ellipses, drawn as shown, the altitude of points on each curve that are the same distance from the vertical axis is the same percentage of the highest altitude in each curve. The percentage according to rate of spread is shown at the top of the figure. In determining the rates of work possible against different rates of spread, the uninfluenced rate was reduced by the applicable percentage shown.

No allowance was made for fatigue, and it is believed not to be a factor in work of such short duration as that represented in the usual successful midday attacks. However, it is a factor in unsuccessful attacks, but for them overnight reinforcement action must be applied. The fatigue curve applied to such attacks is shown in figure 25.

In figure 28, A, the estimated combined influences of crew size on rate of work are shown. These influences are discussed on page 128. More evidence governing this curve is available than was at first recognized. Data and estimates indicate that the work-rate of 50 men is between 40 and 50 percent of that of 1-5 men. From the 45 percent point, the slope of the curve must continue more slowly down to the right for still larger crews, which are not shown. From this point toward the left, the curve must rise at an increasingly faster rate. But no sudden change in slope can be made without producing the result that larger crews will be shown to do less work than smaller ones. In completing the curve from the left side, the drop must increase gradually and then faster. The most rapid decrease in quality of personnel is believed to be in crew sizes between 15 and 25 men.

If this curve correctly approximates the facts, it is conspicuous in indicating the value of using trained men in units of 10 men or less assigned under a trained unit leader to separate sectors of fire perimeter. Although the rates of work assumed are optimistic, if the resulting increase in work-rate should prove to be anywhere near that indicated as possible, the numbers of men greater than 15 shown as needed in the right-hand columns of figure 27 could be reduced 10 to 30 percent. Even more important, faster spreading fires could be controlled with the increased work-rate. That many such fires will occur and require action is evident in figure 28, C.

The data of this figure are the same as those presented in figure 19 on page 70, except that rate of spread is made the dependent variable; dependent upon prevailing severity of burning conditions, as well as upon character of fuel. The terms used in mapping fuels, extreme, high, medium, and low are relative, and the whole range of variation in rates of spread increases with advance in severity of burning conditions. Each of the dots at the 35 percent point indicates a classified fuel's rate of spread expected when burning severity is in the middle of class 4, as rated by the Danger Meter. When burning conditions are the average of class 5, the circles at the 16 percent point show the rates of spread expected in each indicated character of fuel. The positions marked "x" at the 6.6 percent point indicated the rates for average class 6 danger. Thus, the curve at the top of the band called "Low" rate of spread indicates the way in which it is believed the seasonal advance will affect the rate of spread at a particular spot of fuel mapped in the relative classification "low."

It should be pointed out that the rates of spread and the percentages of them that correspond with different ratings of the Danger Meter are not known with any degree of certainty. This uncertainty must continue until severity of burning conditions at the spot where spread occurred, or is taking place, is known. The rates of spread shown as belonging to each class of danger are believed to be those at the spots where the fires occurred. The danger rating at a fire and not at some distant weather station must be estimated by a dispatcher when satisfying control requirements.

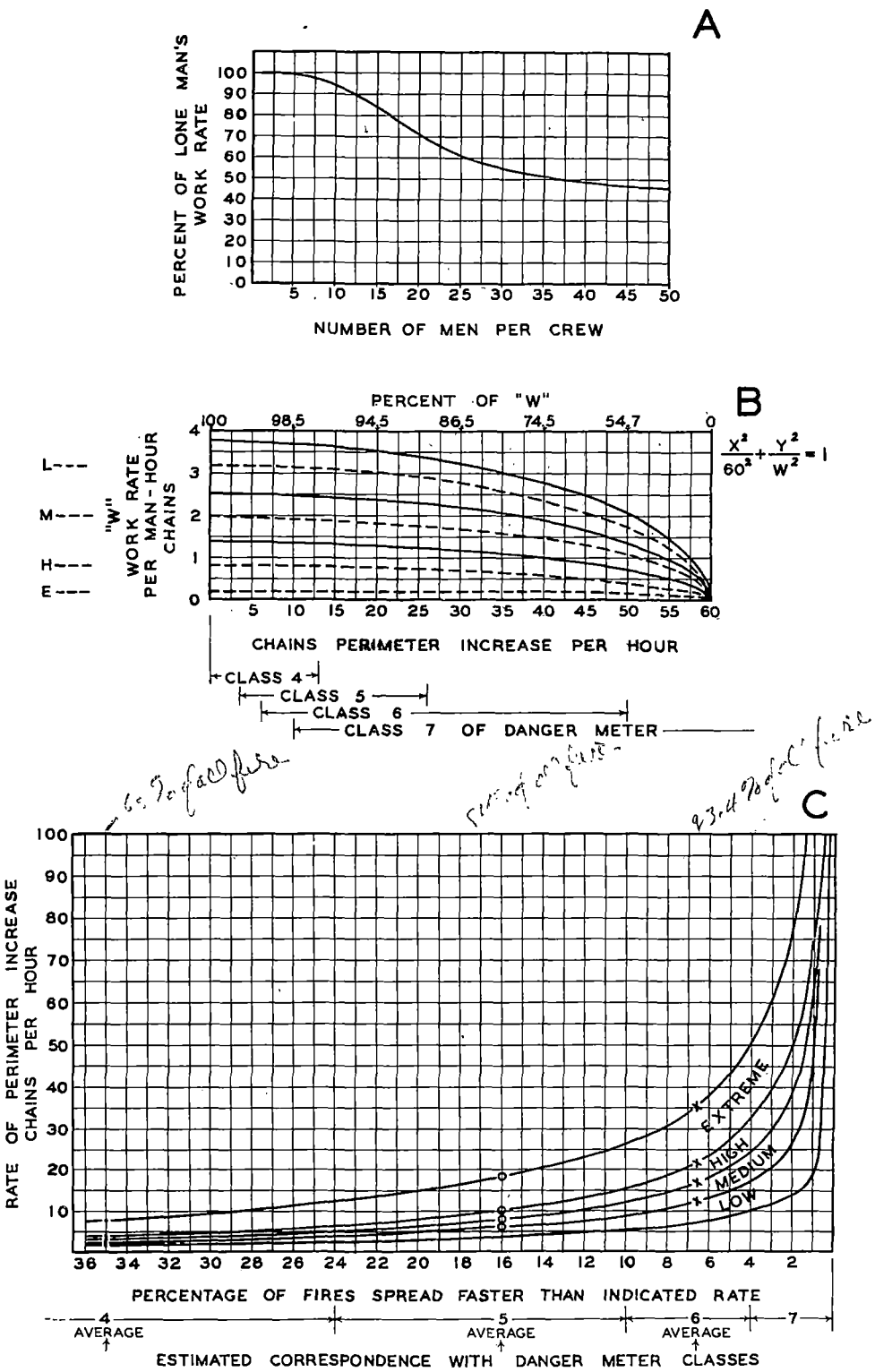


Fig. 28.--Factors involved in the construction and use of figure 27.

A. Influence of crew size on rate of work.

B. Influence of rate of spread on rate of work.

C. Percentage of fires that occurred in fuels of extreme, high, medium, and low rate of spread classifications in western forests of Region One 1921-30, inclusive.

The three sets of points marked on the curves of figure 28, C, represent the steps in degree of burning severity for which plans of preparedness were worked out. The fire control organization required for the least severe of these degrees was called the "Average Season Organization." On the horizontal scale it will be observed that this degree of preparedness satisfies the requirements of 65 percent of all fires. In table 20 the travel time-man power requirements of this degree of danger are shown, in relation to fuel classifications.

The next higher degree of organization planned was called "First Overload," meaning "over" the average requirements. The applicable classified rates of spread are shown circled at 16 percent on the horizontal scale, and in table 21 the travel time-man power requirements are shown according to fuel classes.

The next step for which plans were worked out was called "Second Overload." The rates of spread marked "x" at the 6.6 percent point indicate the degree of danger, and in table 21 are shown the corresponding travel time-man power requirements. The two "Overload" steps are included within a degree of danger called "Maximum," in order to be consistent with the danger called "Minimum" on the opposite side of that called "Average."

Plans were worked out for "Minimum" danger. They require organizations to cover only south and west slopes and flats that carry fuels with rates of spread higher than average. It is probable that the severity of burning conditions prevailing in such places is that represented by class 4 and class 5 of the Danger Meter. These are the places that first show the effects of advancing seasonal danger.

For dispatching purposes tables 20, 21, and 22 are applicable to more steps in danger than those specified. In each of these tables it will be observed that the chains of perimeter increase per hour are shown. The rate 8 chains per hour appears under "Extreme" in table 20 and under "Medium" in table 21, and it will be found that the number of men according to fuel class and travel time is the same. If the dispatcher estimates that the rate of spread is or will be any one of the rates shown in any one of these tables, he can use the table involved as a guide to action. Figures 26 and 27 are applicable to any rate of spread whenever and wherever it occurs. Danger ratings are not involved and whether fuel resistance is known from a map or is only orally described at the time, by one of the natural terms extreme, high, medium, or low, the number of men required when any particular travel time is necessary is shown.

Another use of these data, particularly tables 21 and 22, is to show the real obstacles confronting fire control managers and planners endeavoring to control every fire within the first work period. In table 21, it will be observed that, when rate of spread in "high" class fuels is 10 chains per hour and fuel resistance is high, 25 men cannot be allowed a travel time longer than 2 hours. In table 22 when rate of spread in this same class of fuel is 22 chains per hour, not more than 0.5 hour of time-distance between man-power station and fire can be allowed. Under the intensities of road system planned in inaccessible localities to date and under the degrees of

coverage worked out for smokechaser and light reinforcement action, a very large proportion of area lies beyond either of these time-distances from man power of even one man.

Unless dispatchers are told specifically what the rate of spread at a particular fire will be and at what rate men can extinguish it, instructions to control every fire in the first work period require that the strongest action known to have been successful in similar fuels be taken everywhere. And, back of action, planners apparently should determine the man-power placement and road facilities required to do this. The facts presented here show how difficult this would be.

The gratifying trend toward being specific in fire control action is decidedly hampered by failure for many years to collect the evidence on influences that can show how to be specific. It is legitimate to doubt the accuracy of requirements presented here, and in this the author desires to join. However, it can hardly be doubted that greater accuracy has resulted from making the estimates than from avoiding them. If fatigue were included, the requirements for midday action would be still more stringent. If the requirements are found to be more stringent than required by the degree of danger indicated, it is only necessary to move the action along the scale of danger a few percent to where it is required, but for a smaller percentage of fires.

If the decision is made not to be prepared to satisfy the requirements for successful midday attacks, attention is necessarily focused on the number of 5-10 man units required per unit of area for night reinforcement action. After they are placed they become available for midday action and to some extent they satisfy midday requirements.

Through plan work done to date the degree of coverage that corresponds with different numbers of men and mileages of road per unit of area can be determined. But, since the percentage of fast-spreading fires that would be brought under control by completing different degrees of coverage is not known, definiteness would not be given to the fire control objective by specifying a particular percentage of fires to be controlled within the first work period.

During the period of years required to determine such a correlation, definiteness could be given to the objective by arbitrarily deciding for large areas of similar character the degree of coverage that will be completed in each of the services of fire control, detection and smokechasing and light and heavy reinforcements. Obviously they are interrelated and no one of these services can be planned independently of the others. Until fire control planners, who correspond with designing engineers of other kinds, are told in definite terms what expenditures are permissible and what specifications are desired in different parts of the fire control plant, they cannot work out a structure that will satisfy the board of directors. The function of this progress report is believed to be that of identifying influences which cannot be avoided, determining approximately their degree, and describing methods found satisfactory for planning to different degrees of completeness.

Table 20.--*Number of men required for midday attacks according to travel time and fuel conditions when danger meter rating at fire is the average of class 4.*

according to fuel type ratings for the 20 class combinations

Travel time	Number of men required in indicated fuel resistance 1/ according to average rate of perimeter increase. 2/																	
	Extreme spread 8.0 chains per hour				High spread 4.0 chains per hour				Medium spread 3.3 chains per hour				Low spread 2.6 chains per hour			
	Resistance 3/				Resistance				Resistance				Resistance			
hours	E	H	M	L	E	H	M	L	E	H	M	L	E	H	M	L
	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men
0.00	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.25	5	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1
0.50	6	2	1	1	2	1	1	1	2	1	1	1	1	1	1	1
0.75	8	3	1	1	3	1	1	1	2	1	1	1	2	1	1	1
1.00	12	3	2	1	4	1	1	1	3	1	1	1	2	1	1	1
1.25	20	4	2	1	4	2	1	1	3	1	1	1	2	1	1	1
1.50	35	5	2	2	5	2	1	1	4	1	1	1	2	1	1	1
1.75	50	6	3	2	6	2	1	1	5	1	1	1	3	1	1	1
2.00		8	3	2	7	2	1	1	6	2	1	1	3	1	1	1
2.25		10	4	3	9	3	1	1	7	2	1	1	3	1	1	1
2.50		15	5	4	11	3	2	1	8	2	1	1	5	2	1	1
2.75		33	7	5	16	4	2	1	10	3	1	1	5	2	1	1
3.00			11	7	31	5	2	2	13	3	2	1	6	2	1	1
3.25			25	10	46	6	3	2	25	4	2	1	8	2	1	1
3.50			40	20		8	3	2	39	5	2	2	11	3	1	1
3.75				38		11	4	3	60	7	3	2	15	4	2	1
4.00						26	7	4		9	4	3	29	4	2	1
4.25							14	8		20	6	4	47	6	3	2
4.50							24	16			12	7		8	4	2
4.75								32			22	14		14	5	3
5.00												28		25	16	9
5.25															35	21

1/ Numbers of men shown were read directly from figure 27.
2/ Average rate of increase between zero size and that at arrival. Rates shown dotted in figure 28, C.
3/ Fuel resistance in terms of probable work-rate; E = Extreme, 0.2 chain per man hour for 1-5 man crew size; H = High, 0.8; M = Medium, 2.0; L = Low, 3.2.

Table 21.--*Number of men required for midday attacks according to travel time and fuel conditions when danger meter rating at fire is average of class 5.*

Travel time	Number of men required in indicated fuel resistance 1/ according to average rate of perimeter increase. 2/																	
	Extreme spread 18 chains per hour				High spread 10 chains per hour				Medium spread 8 chains per hour				Low spread 6 chains per hour			
	Resistance 3/				Resistance				Resistance				Resistance			
hours	E	H	M	L	E	H	M	L	E	H	M	L	E	H	M	L
	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men
0.00	13	3	2	1	3	1	1	1	2	1	1	1	1	1	1	1
0.25	50	6	3	2	6	2	1	1	5	2	1	1	3	1	1	1
0.50		11	4	3	10	3	1	1	6	2	1	1	4	2	1	1
0.75		29	7	4	17	4	2	1	8	3	1	1	5	2	1	1
1.00			12	7	37	5	2	2	12	3	2	1	6	3	1	1
1.25			30	12	55	6	3	2	20	4	2	1	8	3	1	1
1.50				20		8	4	2	35	5	2	2	11	3	2	1
1.75				30		12	5	3	50	6	3	2	14	3	2	1
2.00						18	6	4		8	3	2	25	4	2	1
2.25						39	8	5		10	4	3	39	5	2	2
2.50							13	8		15	5	4	50	6	3	2
2.75							25	15		33	7	5		8	3	2
3.00							45	35			11	7		10	4	3
3.25											25	10		17	6	4
3.50											40	20		37	8	5
3.75												38			16	9
4.00															30	20
4.25																44
4.50																
4.75																

1/ Numbers of men shown were read directly from figure 27.
2/ Average rate of increase from zero size to that at arrival. Rates shown circled in figure 28, C.
3/ Fuel resistance in terms of probable work rate; E = Extreme, 0.2 chain per man hour for 1-5 man crew size; H = High, 0.8; M = Medium, 2.0; L = Low, 3.2.

Table 22.--*Number of men required for midday attacks according to travel time and fuel conditions when danger meter rating at fire is average of class 6.*

Travel time	Number of men required in indicated fuel resistance 1/ according to average rate of perimeter increase. 2/																		
	Extreme spread 35 chains per hour				High spread 22 chains per hour				Medium spread 17 chains per hour				Low spread 12 chains per hour						
	Resistance 3/				Resistance				Resistance				Resistance						
hours	E	H	M	L	E	H	M	L	E	H	M	L	E	H	M	L	E	H	M	L
	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men	men
0.00		55	11	6	43	5	2	2	11	3	1	1	5	2	1	1				
0.25						9	4	3	35	5	2	2	9	2	1	1				
0.50						34	7	5	+50	8	4	2	16	4	2	1				
0.75							14	8		17	6	4	42	5	2	2				
1.00							32	15		42	9	5	65	7	3	2				
1.25								30			20	9		9	4	3				
1.50											42	15		15	5	4				
1.75												27		34	7	5				
2.00														55	11	6				
2.25															25	10				
2.50															50	20				
2.75																40				
3.00																				
3.25																				
3.75																				
4.00																				

1/ Numbers of men shown were read directly from figure 27.

2/ Average rate of increase from zero size to that at arrival. Rates shown by "x" in table 28.

3/ Fuel resistance in terms of probable work-rate; E = Extreme, 0.2 chain per man hour for 1-5 man crew size; H = High, 0.8; M = Medium, 2.0; L = Low, 3.2.

CONTENTS OF PLANS; INDEXING, FILING

Maps, overlays, charts and other items belonging to the fire plan of each forest are indexed according to the scheme shown below. All data pertaining to each heading are given the key letter shown. In addition a serial number is given to each item. For example, under J, numbers J-1, J-2, and J-3 are given to the detection coverage maps made for minimum, average, and maximum burning conditions, respectively, and further numbers are used for all other items under detection coverage. The index completed with subheadings is included in the written summary of plan work, and a copy is kept easily available for reference to files in which the plan maps and other data are kept.

The original method of filing plan data was in an imitation leather folio the size of the largest maps. A later and better method, which permits easy access to any two or more maps or tracings to be compared, is to label and roll each sheet separately and place all of them in a cupboard constructed with shelves and compartments.

All data, including the original seen-area map, relating to a particular fireman or crew station (either a potential or occupied station) is placed in a letter-size envelope, labelled with the number and name of the point, and filed in a regular correspondence file drawer.

A copy of map "I", together with "plastacele" silhouettes, is kept in an especially constructed dispatcher's table.

Attention is called to the seen-area maps and silhouettes of the potential detection stations that were not selected for occupancy. Since they show what areas can be seen by going to any of the points studied, they can be used to show dispatchers where to send special detectors after heavy concentrations of lightning strikes and at other times to cover areas not regularly seen or in need of duplicate coverage.

Key Letter	Item
A	Timber types.
B	Burned areas.
C	Occurrence maps, overlays, etc.
D	Fuel-type maps and overlays.
E	Valuation zone maps and data.
F	Total danger maps and data pertaining to them.

Key Letter	Item
G	Allowable smokechaser travel time tracings, etc.
H	Transportation system maps.
I	Index maps showing potential detection and smokechasing positions considered.
J	Detection coverage maps and composites of all kinds.
K	Detection responsibility maps and composites.
L	Patrol coverage data.
M	(Open)
N	Smokechaser coverage maps and composites of all kinds.
O	Smokechaser responsibility maps and composites.
P	Plans for adding smokechasers at regularly occupied stations when burning conditions are in maximum class. Since data included under P and R are related, cross-referencing is necessary.
Q	Man-power placement maps and tracings (locations of man powers).
R	Light reinforcement (small crew) coverage composites and maps.
S	Second-line defense coverage composites and maps.
T	Protection improvement maps and tracings.
U	Fire prevention plan maps, overlays, etc.
V	(Open)
W	Communication maps and tracings.
X	Organization and improvement summarization tables.
Y	(Open)
Z	Follow-up field work plan maps, overlays, etc.

PART III
STATISTICS FOR INDIVIDUAL NATIONAL FORESTS AND OTHER SUPPORTING DATA

Part III consists of analyses originally made for each national forest. These were summarized later for the western forests of the Region and are shown in Parts I and II.

The following is a list of items on which detailed work was done for planning purposes, but which are not ready for presentation.

1. Number of fires and area burned each year 1909-1933 in each forest according to cause.

2. Trend in average discovery time of lightning and man-caused fires in each forest and year.

3. Relation between increasing number of fires and increasing number of detectors per unit of area. The number of fires was determined that occurred each year over a long period of years in the same seen areas of 42 well-distributed lookouts that were occupied continuously throughout the period. It was found that the trend in number of fires, either man-caused or lightning, was the same there as elsewhere. In other words, more fires were not discovered simply because more detectors were placed.

4. The success of each forest in preventing class C fires on days of heavy lightning fire concentrations was investigated thoroughly. It was found that the largest percentage of such fires occurred neither at the highest altitudes where the heaviest concentrations occurred nor at the lowest altitudes, but at intermediate ones.

5. Change in 1910, and since then, in area of single burn fuels.

6. Details of working out and applying composite danger ratings, i.e., the integration of frequency of fire occurrence, fuel danger, and values at stake.

Forest	Owner	Timber type: Lodge-pole	Larch-fir	Sub-alpine	W. white pine	Douglas fir	W. yellow pine	Spruce	Wh. fir-cedar	Cedar-hemlock	Brush-grass	Total protected	Barren & cultivated	Grand total
		Area in acres												
BITTERROOT	Nat'l for.	861,229	6,644	123,582		165,234	206,870	7,138			30,410	1,401,107	64,500	1,465,607
	Alienated	12,767	4,280	0		9,304	49,680	0			16,080	92,111	3,540	95,651
	Total	873,996	10,924	123,582		174,538	256,550	7,138			46,490	1,493,218	68,040	1,561,258
BLACKFEET	Nat'l for.	219,454	268,477	183,932	7,334	24,419	5,900	118,603			2,418	830,517	3,680	834,197
	Alienated	57,846	118,247	1,744	2,109	851	36,780	10,746			507	228,830	3,000	231,830
	Total	277,280	386,724	185,676	9,443	25,270	42,680	129,349			2,925	1,059,347	6,680	1,066,027
CABINET	Nat'l for.	162,063	403,888	201,578	110,826	58,561	135,081	18,642	702	5,235	456	1,097,032	18,401	1,115,433
	Alienated	40,828	113,820	12,224	10,915	18,305	53,899	1,173	610	1,329	1,043	254,146	2,632	256,778
	Total	202,891	517,708	213,802	121,741	76,866	188,980	19,815	1,312	6,564	1,499	1,351,178	21,033	1,372,211
CLEARWATER	Nat'l for.	153,741	39,947	109,999	414,079	23,575	1,684	16,297	36,747		10,065	806,134	15,999	822,133
	Alienated	27,056	1,940	10,188	57,736	888	0	3,815	1,746		3,049	106,418	1,969	108,387
	Total	180,797	41,887	120,187	471,815	24,463	1,684	20,112	38,493		13,114	912,552	17,968	930,520
COEUR D'ALENE	Nat'l for.	12,174	118,378	30,461	379,758	75,191	23,362	1,141		7,076	25,417	672,958	1,386	674,344
	Alienated	1,477	18,093	3,131	48,999	21,567	9,224	0		647	10,258	113,396	2,494	115,890
	Total	13,651	136,471	33,592	428,757	96,758	32,586	1,141		7,723	35,675	786,354	3,880	790,234
FLATHEAD	Nat'l for.	347,136	434,742	494,410	14,910	268,800	6,587	76,660		216	37,381	1,680,842	41,650	1,722,492
	Alienated	27,500	107,171	45,000	4,400	9,780	4,200	10,434		0	3,510	211,995	34,729	246,724
	Total	374,636	541,913	539,410	19,310	278,580	10,787	87,094		216	40,891	1,892,837	76,379	1,969,216
KANIKSU	Nat'l for.	12,264	88,098	86,744	212,792	12,510	2,819	10,852		31,129	4,243	461,451	4,530	465,981
	Alienated	4,738	28,219	3,897	73,020	9,817	3,792	1,922		5,732	4,584	135,721	4,858	140,579
	Total	17,002	116,317	90,641	285,812	22,327	6,611	12,774		36,861	8,827	597,172	9,388	606,560
KOOTENAI	Nat'l for.	414,672	376,517	277,982	86,884		104,645	99,590		19,681	3,677	1,383,648	18,788	1,402,436
	Alienated	22,703	118,779	30,228	9,325		70,392	761		4,589	687	257,464	13,017	270,481
	Total	437,375	495,296	308,210	96,209		175,037	100,351		24,270	4,364	1,641,112	31,805	1,672,917
LOLO	Nat'l for.	573,485	380,112	226,953	3,687	110,122	123,995	66,112	10,830		9,566	1,504,862	14,273	1,519,135
	Alienated	162,392	189,860	89,715	184	25,953	116,699	20,073	1,812		1,897	608,585	8,226	616,811
	Total	735,877	569,972	316,668	3,871	136,075	240,694	86,185	12,642		11,463	2,113,447	22,499	2,135,946
NEZPERCE	Nat'l for.	546,641	40,993	35,880		198,375	177,670	11,933	208,936		97,912	1,318,340	1,980	1,320,320
	Alienated	6,585	861	0		3,039	10,638	0	405		17,219	38,747	3,300	42,047
	Total	553,226	41,854	35,880		201,414	188,308	11,933	209,341		115,131	1,357,087	5,280	1,362,367
PEND OREILLE	Nat'l for.	24,896	120,725	245,331	153,426		40,207	39,284		2,501	3,483	629,853	48,493	678,346
	Alienated	322	39,122	36,802	57,286		11,962	7,990		2,715	0	156,199	1,403	~~127,602~~ 157,402
	Total	25,218	159,847	282,133	210,712		52,169	47,247		5,216	3,483	786,052	49,896	835,948
SELWAY	Nat'l for.	331,692	739	230,005	4,634	285,026	83,662	87,622	281,191		6,088	1,310,659	17,715	1,328,374
	Alienated	0	0	0	0	428	900	0	2,000		0	3,328	316	3,644
	Total	331,692	739	230,005	4,634	285,454	84,562	87,622	283,191		6,088	1,313,987	18,031	1,332,018
ST. JOE	Nat'l for.	118,925	49,181	71,536	272,254	5,714	10,672	23,977		2,124	29,635	584,018	7,037	591,055
	Alienated	28,947	31,784	14,669	191,581	3,357	15,942	6,133		1,778	13,877	308,068	6,869	314,937
	Total	147,872	80,965	86,205	463,835	9,071	26,614	30,110		3,902	43,512	892,086	13,906	905,992
TOTALS	Nat'l for.	3,778,352	2,328,441	2,318,393	1,660,584	1,227,527	923,154	577,851	538,406	67,962	260,751	13,681,421	258,432	13,939,853
	Alienated	393,161	772,176	247,598	455,555	103,249	384,108	63,947	6,573	16,790	72,711	2,515,008	86,353	2,601,361
	Total	4,171,513	3,100,617	2,565,991	2,116,139	1,330,816	1,307,262	640,898	544,979	84,752	333,462	16,196,429	344,785	16,541,214

TABLE 23.—TIMBER TYPE ACREAGES IN INDICATED NATIONAL FORESTS.

FOREST		TIMBER TYPE (ACRES)										TOTAL
		LODGE-POLE PINE	LARCH DOUGLAS FIR	SUB-ALPINE	WESTERN WHITE PINE	DOUGLAS FIR	WESTERN YELLOW PINE	SPRUCE	CEDAR WHITE FIR	CEDAR HEMLOCK WH. FIR	BRUSH AND GRASS	
BITTERROOT	ACTUAL	3,728		11,160		3,780	13,486				1,362	33,516
	PERMISSIBLE	87,400	273	14,830		5,236	5,131	71			11,622	124,563
	DIFFERENCE	− 83,672	− 273	− 3,670		− 1,456	+ 8,355	− 71			− 10,260	− 91,047
BLACKFEET	ACTUAL	49,488	66,355	16,034	3	512	77	3,868	3		34	136,374
	PERMISSIBLE	27,728	9,668	22,281	94	758	854	1,294			731	63,408
	DIFFERENCE	+ 21,760	+ 56,687	− 6,247	− 91	− 246	− 777	+ 2,574	+ 3		− 697	+ 72,966
CABINET	ACTUAL	711	8,891	1,929	5,381	514	5,400	2	1	16	1,300	24,145
	PERMISSIBLE	20,289	12,943	25,656	1,217	2,306	3,780	198	26	131	375	66,921
	DIFFERENCE	− 19,578	− 4,052	− 23,727	+ 4,164	− 1,792	+ 1,620	− 196	− 25	− 115	+ 925	− 42,776
CLEARWATER	ACTUAL	260	4,603	234	37,983			4	7	2,333	1,282	46,706
	PERMISSIBLE	18,080	1,047	14,422	4,718	734	34	201	770		3,278	43,284
	DIFFERENCE	− 17,820	+ 3,556	− 14,188	+ 33,265	− 734	− 34	− 197	− 763	+ 2,333	− 1,996	+ 3,422
COEUR D'ALENE	ACTUAL	101	3,142	504	51,003	3	2,152	923	3	2	5,023	62,856
	PERMISSIBLE	1,365	3,412	4,031	4,288	2,903	651	11		155	8,919	25,735
	DIFFERENCE	− 1,264	− 270	− 3,527	+ 46,715	− 2,900	+ 1,501	+ 912	+ 3	− 153	− 3,896	+ 37,121
FLATHEAD	ACTUAL	17,853	59,921	19,178	4,885	18,708	390	6,370		537	1,814	129,656
	PERMISSIBLE	37,464	13,548	64,729	193	8,357	216	871		4	10,223	135,605
	DIFFERENCE	− 19,611	+ 46,373	− 45,551	+ 4,692	+ 10,351	+ 174	+ 5,499	−	+ 533	− 8,409	− 5,949
KANIKSU	ACTUAL	2,531	36,658	46,329	118,428	11	1,563	1,945		7,043	1,392	215,900
	PERMISSIBLE	1,700	2,908	10,877	2,858	670	132	128		737	2,207	22,217
	DIFFERENCE	+ 831	+ 33,750	+ 35,452	+ 115,570	− 659	+ 1,431	+ 1,817		+ 6,306	− 815	+ 193,683
KOOTENAI	ACTUAL	21,212	13,798	2,077	4,210	161	8,885	325	271	393	76	51,408
	PERMISSIBLE	43,737	12,382	36,985	962		3,501	1,004		486	1,091	100,148
	DIFFERENCE	− 22,525	+ 1,416	− 34,908	+ 3,248	+ 161	+ 5,384	− 679	+ 271	− 93	− 1,015	− 48,740
LOLO	ACTUAL	6,451	4,783	1,586		443	10,940	549	315		2,017	27,084
	PERMISSIBLE	73,587	14,249	38,000	39	4,082	4,814	862	253		2,866	138,752
	DIFFERENCE	− 67,136	− 9,466	− 36,414	− 39	− 3,639	+ 6,126	− 313	+ 62		− 849	− 111,668
NEZPERCE	ACTUAL	4,185	2	90			8,828				2,302	15,407
	PERMISSIBLE	55,323	1,046	4,306		6,042	3,766	119	4,187		28,783	103,572
	DIFFERENCE	− 51,138	− 1,044	− 4,216		− 6,042	+ 5,062	− 119	− 4,187		− 26,481	− 88,165
PEND OREILLE	ACTUAL	11,634	4,881	20,792	27,791	318	10,283	1,397	7	602	7,288	84,993
	PERMISSIBLE	2,522	3,996	33,856	2,107		1,043	473		104	871	44,972
	DIFFERENCE	+ 9,112	+ 885	− 13,064	+ 25,684	+ 318	+ 9,240	+ 924	+ 7	+ 498	+ 6,417	+ 40,021
SELWAY	ACTUAL	144	59	20,133	3	1,317	1,510	326	53,030		100	76,622
	PERMISSIBLE	33,169	19	27,601	46	8,564	1,691	876	5,664		1,522	79,152
	DIFFERENCE	− 33,025	+ 40	− 7,468	− 43	− 7,247	− 181	− 550	+ 47,366		− 1,422	− 2,530
ST. JOE	ACTUAL	12,882	7,812	1,418	50,061	18	1,920	880	1,650	43	1,448	78,132
	PERMISSIBLE	14,787	2,024	10,345	4,639	272	532	301		78	10,878	43,856
	DIFFERENCE	− 1,905	+ 5,788	− 8,927	+ 45,422	− 254	+ 1,388	+ 579	+ 1,650	− 35	− 9,430	+ 34,276
TOTALS	ACTUAL	131,180	210,905	141,464	299,748	25,785	65,434	16,589	55,287	10,969	25,438	982,799
	PERMISSIBLE	417,151	77,515	307,919	21,161	39,924	26,145	6,409	10,900	1,695	83,366	992,185
	DIFFERENCE	− 285,971	+ 133,390	− 166,455	+ 278,587	− 14,139	+ 39,289	+ 10,180	+ 44,387	+ 9,274	− 57,928	− 9,386

TABLE 24.—ACTUAL AREA BURNED, ALLOWABLE BURN AND THE DIFFERENCE BY TYPES FOR INDICATED NATIONAL FORESTS.
1921 TO 1930 INCLUSIVE

FOREST	OWNER	TIMBER TYPE										TOTAL	PERMISSIBLE BURN PER 100,000 ACRES OF PROTECTED TYPES
		LODGEPOLE PINE	LARCH DOUG.—FIR	SUBALPINE	WESTERN WH. PINE	DOUGLAS FIR	WESTERN YELLOW PINE	SPRUCE	WH. FIR CEDAR	CED.—HEM. WH. FIR	BRUSH GRASS		
		10.0%	2.5%	12.0%	1.0%	3.0%	2.0%	1.0%	2.0%	2.0%	25.0%		
		PER CENT PERMISSIBLE ACRES PERMISSIBLE BURN											
BITTERROOT	NAT'L FOR.	86,121	166	14,830	0	4,957	4,137	71			7,602	117,884	
	ALIENATED	1,279	107	0	0	279	994	0			4,020	6,679	
	TOTAL	87,400	273	14,830	0	5,236	5,131	71			11,622	124,563	8,360
BLACKFEET	NAT'L FOR.	21,943	6,712	22,072	73	733	118	1,186			605	53,442	
	ALIENATED	5,785	2,956	209	21	25	736	108			126	9,966	
	TOTAL	27,728	9,668	22,281	94	758	854	1,294			731	63,408	5,980
CABINET	NAT'L FOR.	16,206	10,097	24,189	1,108	1,757	2,703	186	14	105	114	56,479	
	ALIENATED	4,083	2,846	1,467	109	549	1,077	12	12	26	261	10,442	
	TOTAL	20,289	12,943	25,656	1,217	2,306	3,780	198	26	131	375	66,921	4,950
CLEARWATER	NAT'L FOR.	15,374	999	13,199	4,141	707	34	163	735		2,516	37,868	
	ALIENATED	2,706	48	1,223	577	27	0	38	35		762	5,416	
	TOTAL	18,080	1,047	14,422	4,718	734	34	201	770		3,278	43,284	4,750
COEUR D'ALENE	NAT'L FOR.	1,217	2,960	3,655	3,798	2,256	467	11		142	6,354	20,860	
	ALIENATED	148	452	376	490	647	184	0		13	2,565	4,875	
	TOTAL	1,365	3,412	4,031	4,288	2,903	651	11		155	8,919	27,735	3,280
FLATHEAD	NAT'L FOR.	34,714	10,871	59,329	149	8,064	132	767		4	9,345	123,375	
	ALIENATED	2,750	2,677	5,400	44	298	84	104			878	12,230	
	TOTAL	37,464	13,548	64,729	193	8,357	216	871		4	10,223	135,605	7,170
KANIKSU	NAT'L FOR.	1,226	2,202	10,409	2,128	375	56	109		622	1,061	18,188	
	ALIENATED	474	706	468	730	295	76	19		115	1,146	4,029	
	TOTAL	1,700	2,908	10,877	2,858	670	132	128		737	2,207	22,217	3,720
KOOTENAI	NAT'L FOR.	41,467	9,413	33,358	869	0	2,093	996		394	919	89,509	
	ALIENATED	2,270	2,969	3,627	93	0	1,408	8		92	172	10,639	
	TOTAL	43,737	12,382	36,985	962	0	3,501	1,004		486	1,091	100,148	6,100
LOLO	NAT'L FOR.	57,348	9,503	27,234	37	3,304	2,480	661	217		2,392	103,176	
	ALIENATED	16,239	4,746	10,766	2	778	2,334	201	36		474	35,576	
	TOTAL	73,587	14,249	38,000	39	4,082	4,814	862	253		2,866	138,752	6,570
NEZPERCE	NAT'L FOR.	54,664	1,024	4,306	0	5,951	3,553	119	4,179		24,478	98,274	
	ALIENATED	659	22	0	0	91	213	0	8		4,305	5,298	
	TOTAL	55,323	1,046	4,306	0	6,042	3,766	119	4,187		28,783	103,572	7,630
PEND OREILLE	NAT'L FOR.	2,194	3,015	29,440	1,534	0	804	394		50	871	38,602	
	ALIENATED	28	981	4,416	573	0	239	79		54		6,370	
	TOTAL	2,522	3,996	33,856	2,107	0	1,043	473		104	871	44,972	5,720
SELWAY	NAT'L FOR.	33,169	19	27,601	46	8,551	1,673	876	5,624		1,522	79,081	
	ALIENATED	0	0	0	0	13	18	0	40		0	71	
	TOTAL	33,169	19	27,601	46	8,564	1,691	876	5,664		1,522	79,152	6,020
ST. JOE	NAT'L FOR.	11,892	1,230	8,585	2,723	171	213	240		42	7,409	32,505	
	ALIENATED	2,895	794	1,760	1,916	101	319	61		36	3,469	11,351	
	TOTAL	14,787	2,024	10,345	4,639	272	532	301		78	10,878	43,856	4,920
TOTALS	NAT'L FOR.	377,835	58,211	278,207	16,606	36,826	18,463	5,779	10,769	1,359	65,188	869,243	
	ALIENATED	39,316	19,304	29,712	4,555	3,098	7,682	630	131	336	18,178	122,942	
	TOTAL	417,151	77,515	307,919	21,161	39,924	26,145	6,409	10,900	1,695	83,366	992,185	6,126

TABLE 25.—ALLOWABLE BURN IN 10 YEARS BY TIMBER TYPES FOR INDICATED NATIONAL FORESTS.

TIMBER TYPE (AND PERCENT PERMISSIBLE BURN IN TEN YEARS)	TOTAL AREA		YEAR 1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	TOTAL
								ACRES					
LODGEPOLE 10.0%	4,171,513	ACTUAL BURN	5,247	1,424	17	3,408	17,140	65,627	85	6,091	30,774	1,367	131,180
		PERMISSIBLE	18,700	18,700	175	18,700	18,700	152,301	175	18,700	152,300	18,700	417,151
		DIFFERENCE	− 13,453	− 17,276	− 158	− 15,292	− 1,560	− 86,674	− 90	− 12,609	− 121,526	− 17,333	− 285,971
LARCH FIR 2.5%	3,100,617	ACTUAL BURN	10,363	7,689	2,285	5,623	13,310	100,117	7	9,331	60,450	1,730	210,905
		PERMISSIBLE	2,770	2,770	957	2,770	2,770	29,490	957	2,770	29,491	2,770	77,515
		DIFFERENCE	+ 7,593	+ 4,919	+ 1,328	+ 2,853	+ 10,540	+ 70,627	− 950	+ 6,561	+ 30,959	− 1,040	+ 133,390
SUBALPINE 12.0%	2,565,991	ACTUAL BURN	2,172	508	156	2,086	3,272	46,957	33	467	85,467	346	141,464
		PERMISSIBLE	3,050	3,050	100	3,050	3,050	144,709	100	3,050	144,710	3,050	307,919
		DIFFERENCE	− 878	− 2,542	+ 56	− 964	+ 222	− 97,752	− 67	− 2,583	− 59,243	− 2,704	− 166,455
WHITE PINE 1.0%	2,116,139	ACTUAL BURN	4,188	21,392	14,859	10,001	18,453	167,370	1,334	22,487	37,909	1,745	299,748
		PERMISSIBLE	925	925	530	925	925	7,276	530	925	7,275	925	21,161
		DIFFERENCE	+ 3,263	+ 20,467	+ 14,329	+ 9,076	+ 17,528	+ 160,094	+ 814	+ 21,562	+ 30,634	+ 820	+ 278,587
DOUGLAS FIR 3.0%	1,330,816	ACTUAL BURN	375	151	80	291	622	18,819	801	77	4,552	17	25,785
		PERMISSIBLE	570	570	100	570	570	18,152	100	570	18,152	570	39,924
		DIFFERENCE	− 195	− 419	− 20	− 279	+ 52	+ 667	+ 701	− 493	− 13,600	− 553	− 14,139
YELLOW PINE 2.0%	1,307,262	ACTUAL BURN	3,461	5,776	1,345	12,328	1,614	13,440	503	4,638	21,906	423	65,434
		PERMISSIBLE	1,875	1,875	392	1,875	1,875	7,055	392	1,875	7,056	1,875	26,145
		DIFFERENCE	+ 1,586	+ 3,901	+ 953	+ 10,453	− 261	+ 6,385	+ 111	+ 2,763	+ 14,850	− 1,452	+ 39,289
SPRUCE 1.0%	640,898	ACTUAL BURN	957	952	370	68	2,196	5,163	11	15	6,857	0	16,589
		PERMISSIBLE	267	267	64	267	267	2,340	64	267	2,339	267	6,409
		DIFFERENCE	+ 690	+ 685	+ 306	− 199	+ 1,929	+ 2,823	− 53	− 252	+ 4,518	− 267	+ 10,180
WHITE FIR CEDAR 2.0%	544,979	ACTUAL BURN	231	1,984	498	2,141	515	296	850	92	47,201	1,479	55,287
		PERMISSIBLE	216	216	110	216	216	4,692	110	216	4,692	216	10,900
		DIFFERENCE	+ 15	+ 1,768	+ 388	+ 1,925	+ 299	− 4,396	+ 740	− 124	+ 42,509	+ 1,263	+ 44,387
CEDAR, HEM., WH. FIR 2.0%	84,752	ACTUAL BURN	3	166	34	790	1,192	6,030	6	1,655	1,077	16	10,969
		PERMISSIBLE	100	100	50	100	100	498	50	100	497	100	1,695
		DIFFERENCE	− 97	+ 66	− 16	+ 690	+ 1,092	+ 5,532	− 44	+ 1,555	+ 580	− 84	+ 9,274
BRUSH GRASS 25.0%	333,462	ACTUAL BURN	2,953	1,625	111	2,679	3,648	5,946	62	1,549	6,139	726	25,438
		PERMISSIBLE	7,250	7,250	100	7,250	7,250	19,833	100	7,250	19,833	7,250	83,366
		DIFFERENCE	− 4,297	− 5,625	+ 11	− 4,571	− 3,602	− 13,887	− 38	− 5,701	− 13,694	− 6,524	− 57,928
TOTALS 6.13%	16,196,429	ACTUAL BURN	29,950	41,667	19,755	39,415	61,962	429,765	3,702	46,402	302,332	7,849	982,799
		PERMISSIBLE	35,723	35,723	2,578	35,723	35,723	386,346	2,578	35,723	386,345	35,723	992,185
		DIFFERENCE	− 5,773	+ 5,944	+ 17,177	+ 3,692	+ 26,239	+ 43,419	+ 1,124	+ 10,679	− 84,013	− 27,874	− 9,386

TABLE 26.—AREA BURNED BY TIMBER TYPES – 1921 TO 1930 (GROSS AREAS WITHIN NATIONAL FOREST BOUNDARIES)

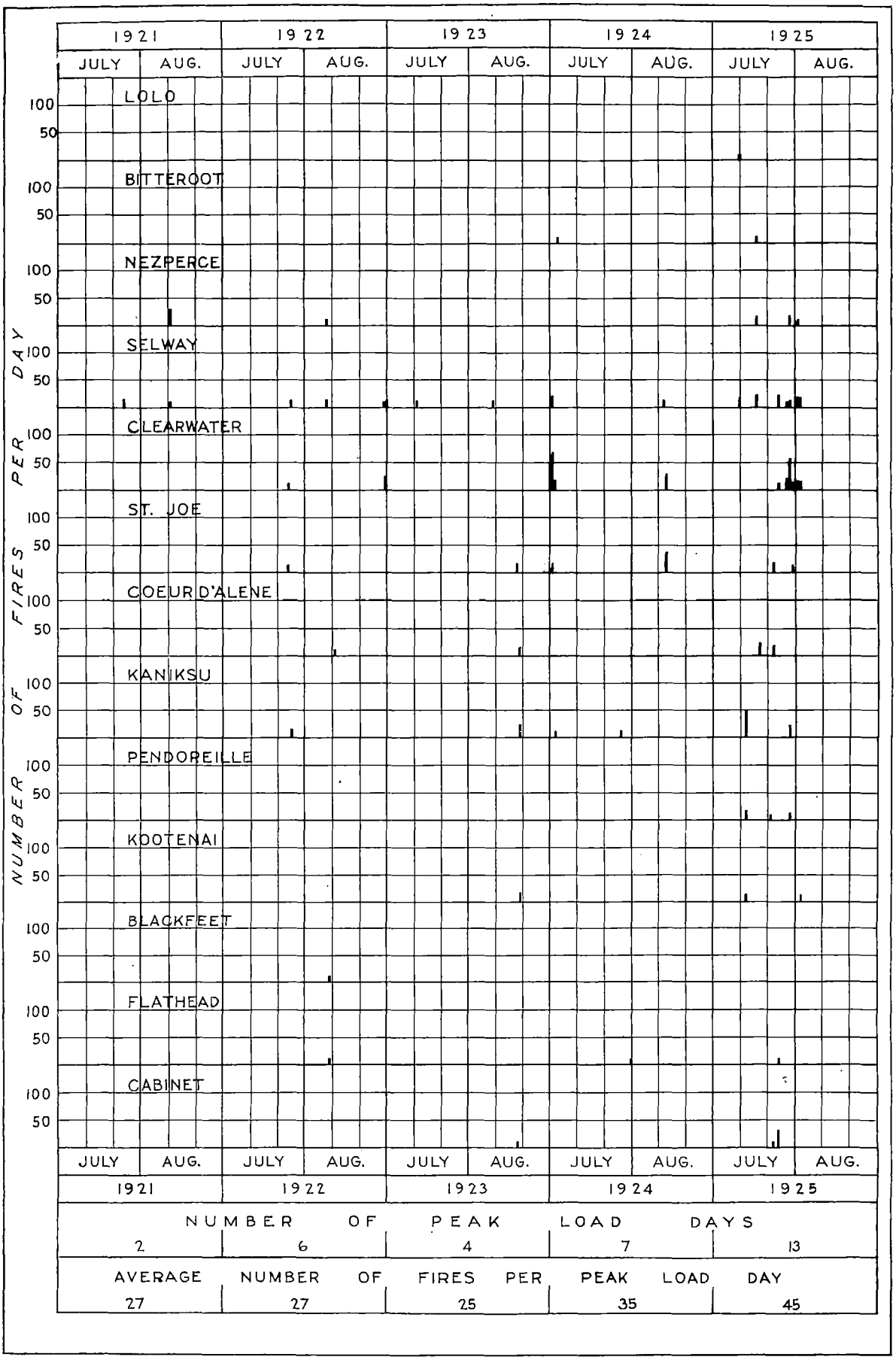
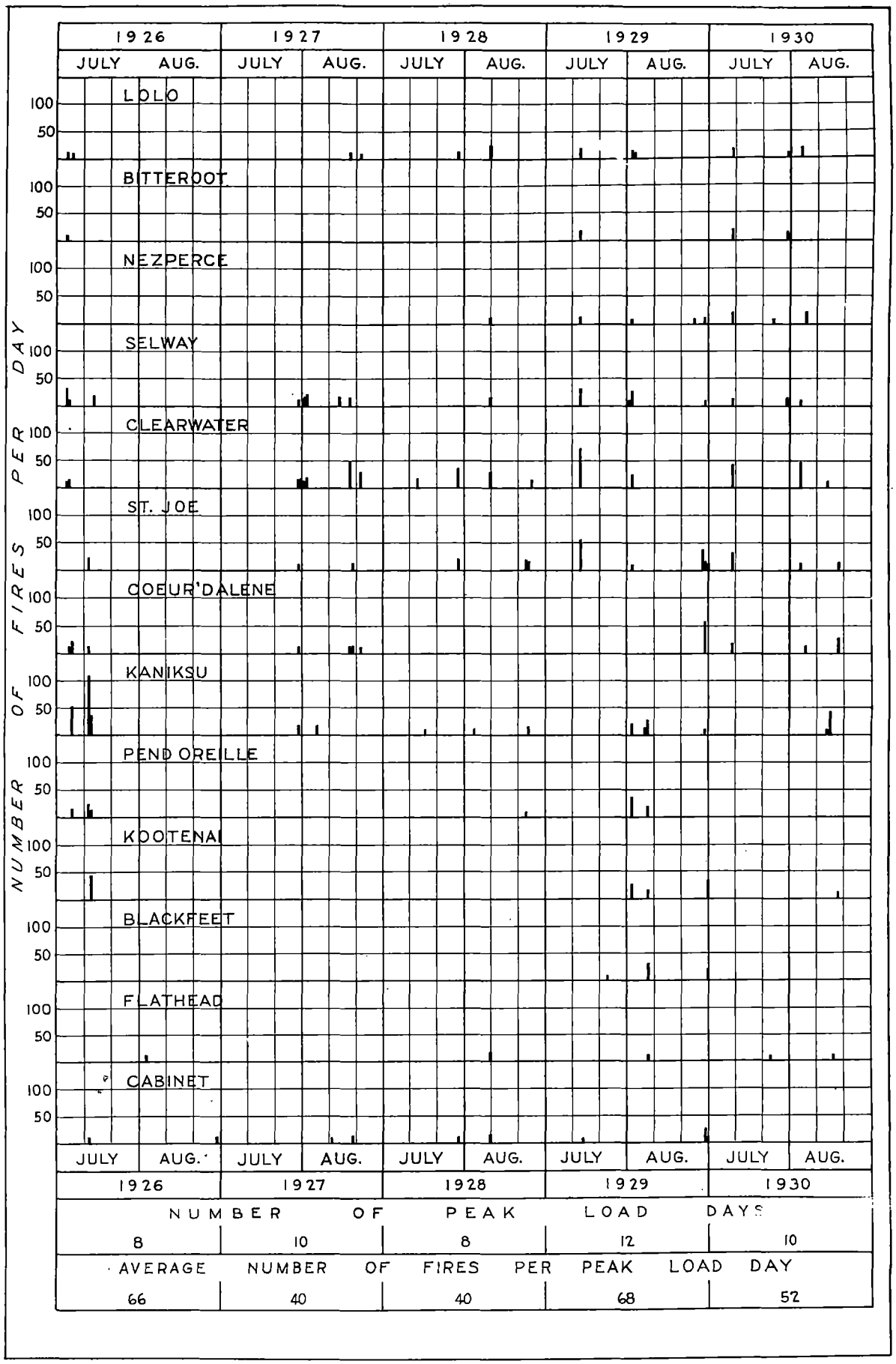


Fig. 29.—Days of July and August 1921-25, inclusive, on which 10 or more lightning fires occurred in one or more of the indicated national forests.



NUMBER OF PEAK LOAD DAYS				
1926	1927	1928	1929	1930
8	10	8	12	10

AVERAGE NUMBER OF FIRES PER PEAK LOAD DAY				
1926	1927	1928	1929	1930
66	40	40	68	52

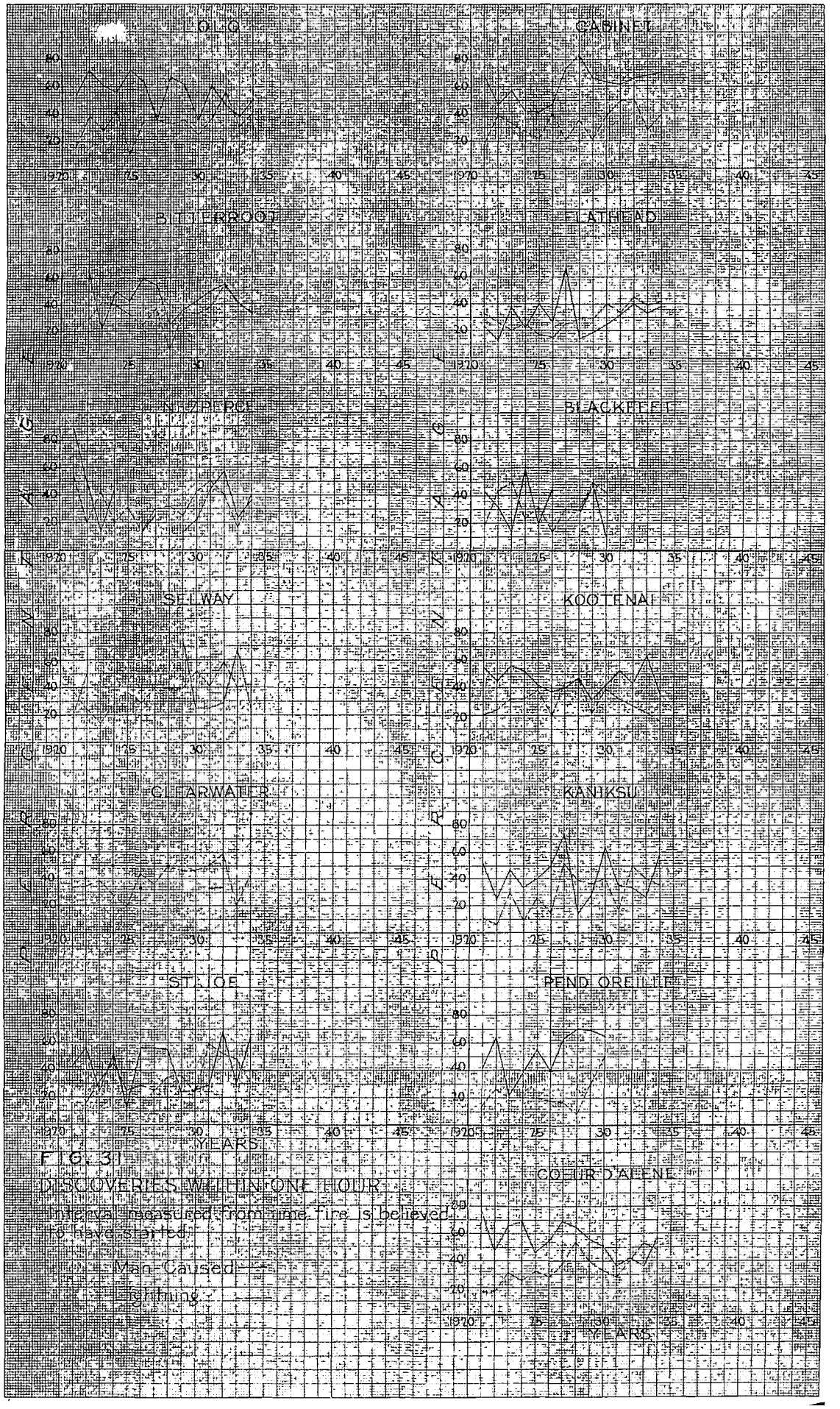


FIG. 31

DISCOVERIES WITHIN ONE HOUR

Interval measured from time fire is believed to have started.

Man Caused

Lightning

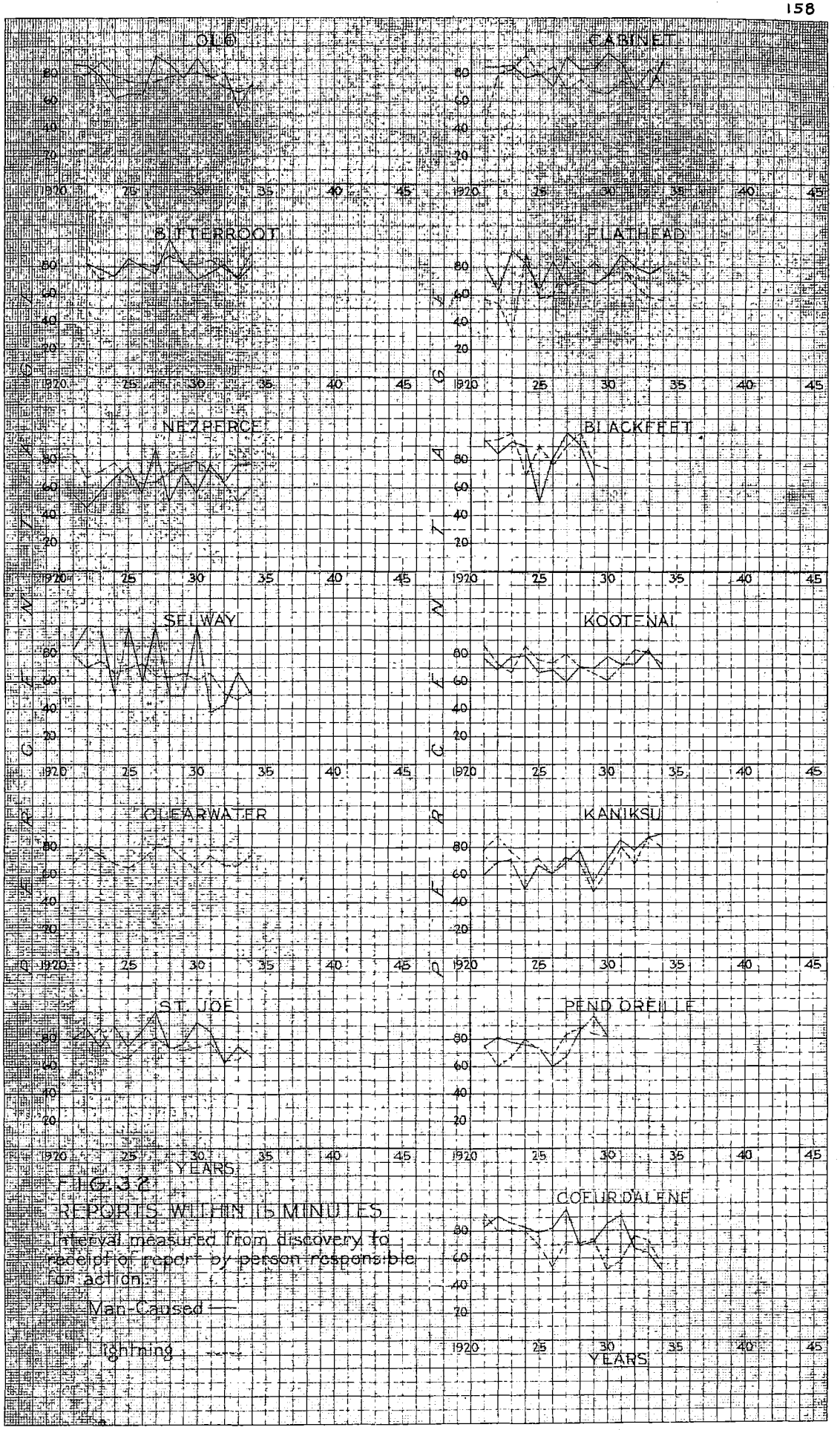


FIG. 32

REPORTS WITHIN 15 MINUTES

Interval measured from discovery to receipt of report by person responsible for action.

Man-Caused —

Lightning - - - -

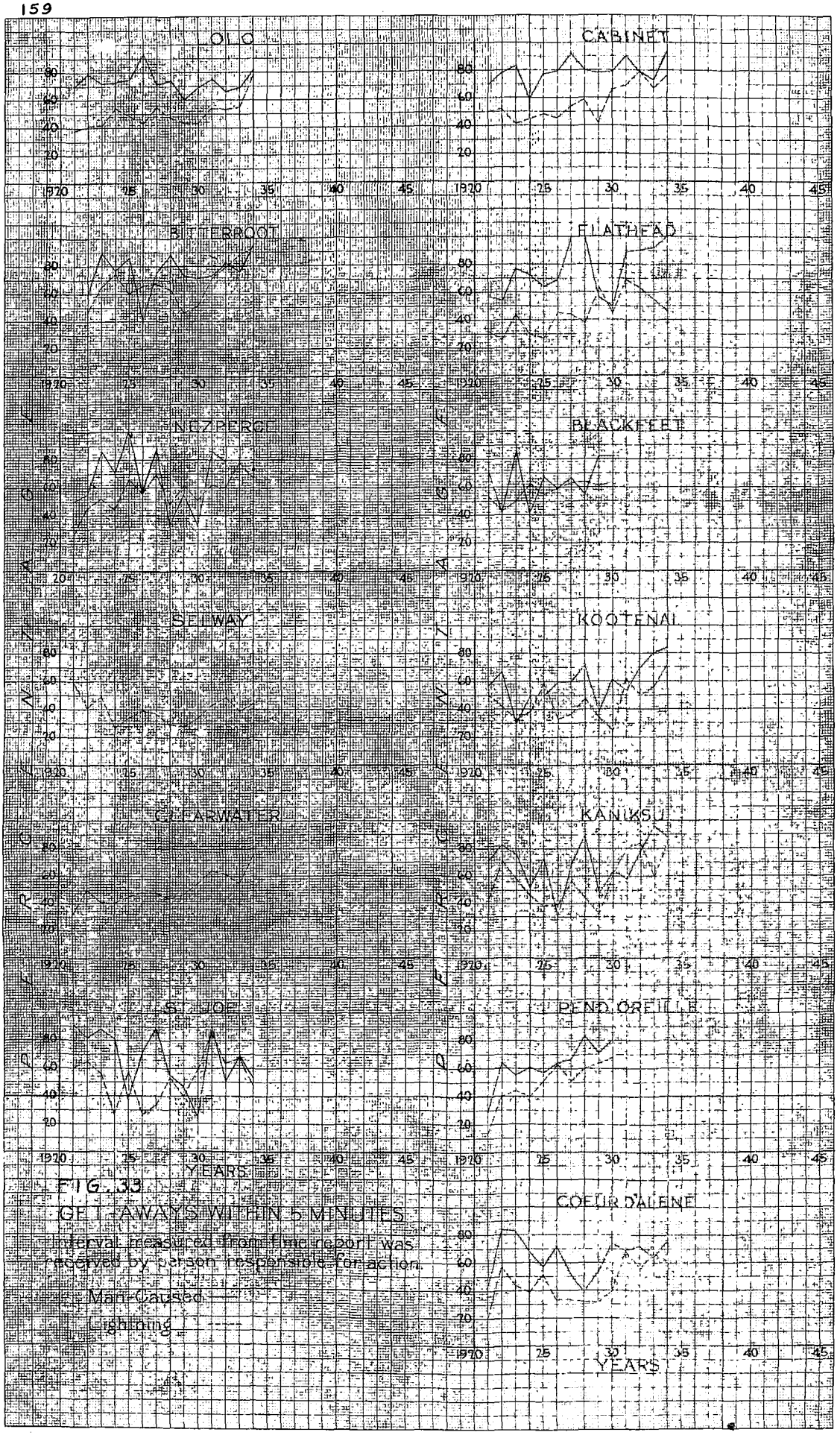


FIG. 33

GET-AWAYS WITHIN 5 MINUTES

Interval measured from time report was received by person responsible for action.

Man-Caused

Lightning

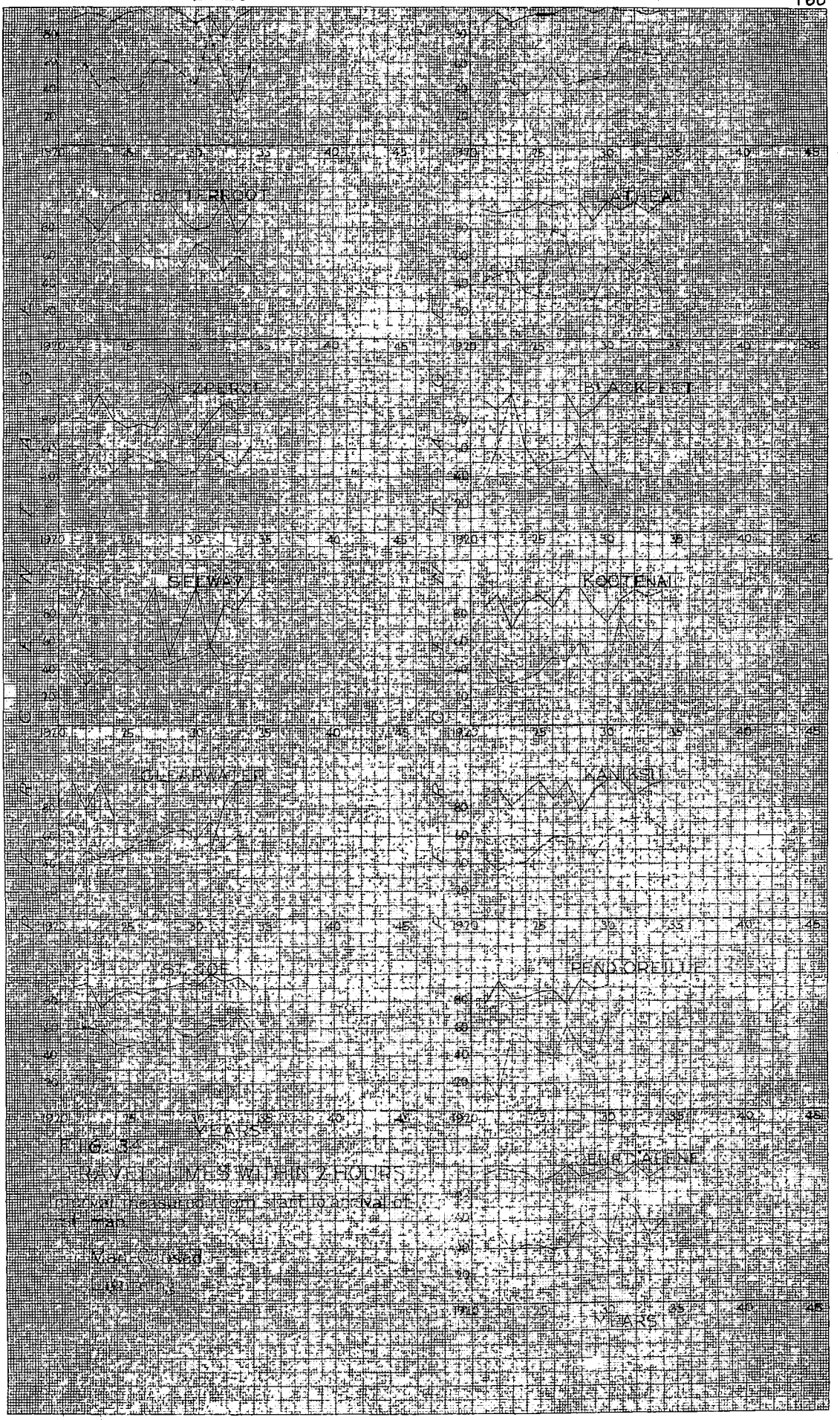


FIG. 34

RAVEL MILES WITHIN 2 HOURS

Interval measured from start to arrival of
1 man.
More needed.
Lost.

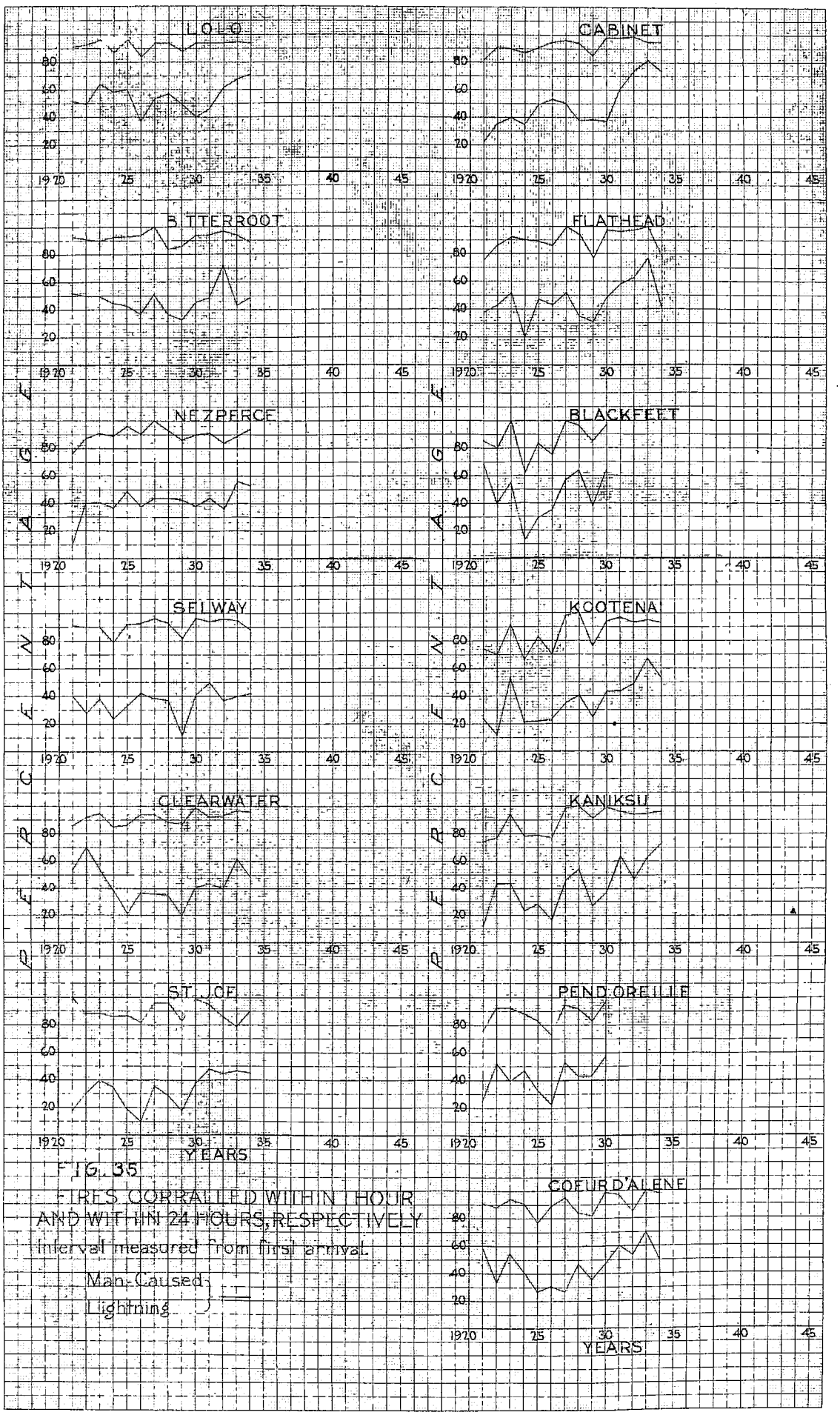


FIG. 35

FIRES CORRALLED WITHIN 1 HOUR AND WITHIN 24 HOURS, RESPECTIVELY

Interval measured from first arrival.

Man-Caused

Lightning

Table 27. Men available, stations, housing of fireman stations, and use of temporary personnel, 1921-35 1/

Item	Value for season indicated													
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Men, including C.C.C.----Number													13,674	17,731	
Men, excluding C.C.C.----Number	1,261	1,704	1,508	1,969	1,755	2,357	2,357	2,211	2,306	3,170	3,882	3,526	3,330	6,200	
Regular temporary force-----Number	601	679	692	720	722	753	853	870	926	911	956	1,001	1,000	816	
Regular firemen ---Number	499	542	586	583	597	631	711	721	736	749	803			719	
Stations of regular firemen---Number	396	427	454	445	466	498	548	585	621	667	776			719	
Fireman stations housed----Number	188	227	246	263	277	291	346	424	492	560				606	
Part of regular temporary force used as overhead and service of supply----Percent	17	20	15	19	17	16	17	17	20	18	16				
Firemen per station ---Number	1.26	1.27	1.29	1.31	1.28	1.27	1.30	1.23	1.18	1.12	1.03			1.00	
Emergency guards ---Number	212	93	0	146	101	267	101	134	264	338	826	0	0	154	
Men in project crews available for fire duty--Number	448	932	816	1,103	932	1,337	1,403	1,207	1,115	1,921	2,100	2,525	2,328	5,203	

1/ Sources of data, and values for individual forest units, are given in tables 28-37, inclusive.

Table 28. Total forces available, including Civilian Conservation Corps men, in seasons 1933-35

National-forest unit 1/	Number of men available in designated season 2/					
	1933		1934		1935	
	C.C.C.	Total 3/	C.C.C.	Total 3/	C.C.C.	Total 3/
Nezperce	133	205	214	367		
Selway	400	478	150	326		
Clearwater	2,002	2,150	1,116	2,219		
St. Joe	2,700	3,433	2,955	4,208		
Coeur d'Alene	1,600	2,940	2,879	4,080		
Kaniksu	892	1,076	2,838	3,116		
Pend Oreille	196	348				
Kootenai	575	688	421	777		
Flathead	192	302	347	591		
Blackfeet	380	466				
Cabinet	906	1,026	220	648		
Lolo	0	114	0	253		
Bitterroot	370	450	418	1,172		
Total	10,346	13,674	11,558	17,731		

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Data obtained from Operation's form 930 fire statistics.

3/ Included in totals, together with C.C.C. men, are regular temporary force, emergency guards, and project crews.

Table 29. Total forces available, exclusive of Civilian Conservation Corps men, in seasons 1921-35

National-forest unit 1/	Number of men available 2/ in designated season														
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Nezperce	136	141	94	136	118	143	191	154	129	144	230	131	72	153	
Selway	126	177	125	174	135	204	215	249	219	306	362	190	78	176	
Clearwater	152	190	174	215	202	226	213	234	245	472	757	734	148	1,103	
St. Joe	100	160	138	146	155	191	225	174	175	249	318	622	733	1,253	
Coeur d'Alene	63	101	98	99	138	220	183	196	203	233	222	325	1,340	1,201	
Kaniksu	56	82	81	89	67	223	176	147	167	258	283	238	184	278	
Pend Oreille	67	102	90	79	96	114	136	128	122	143	232	194	152		
Kootenai	58	142	132	285	193	220	207	151	183	222	211	184	113	357	
Flathead	113	149	153	171	148	231	175	181	196	334	401	209	110	244	
Blackfeet	57	95	88	113	126	166	180	153	175	218	211	173	86		
Cabinet	48	110	95	131	106	121	137	124	134	158	215	190	120	428	
Lolo	86	92	63	71	84	88	95	104	115	134	301	247	114	253	
East Selway	18	19	19	68	45	63	64	49	66	70					
Missoula	85	63	61	98	71	57	50	64	62	84					
Bitterroot	26	31	39	48	35	42	62	56	46	64	139	89	80	754	
Salmon Mtn.	70	50	58	46	36	48	48	47	69	81					
Total	1,261	1,704	1,508	1,969	1,755	2,357	2,357	2,211	2,306	3,170	3,882	3,526	3,330	6,200	

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Numbers given include the following: Regular temporary force, emergency guards, and project crews. The figures used for regular temporary force are averages for six 10-day periods of July and August; those used for each of the other forces are maxima for the period of July or August that contained the worst regional fire emergency of the season. Data were obtained from Operation's form 930 fire statistics.

Table 30. Regular temporary fire-control force provided for burning conditions classed as average

National-forest unit 1/	Number of men employed 2/ in designated season													
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Nezperce	35	39	39	39	41	41	49	57	52	53	67	59	54	40	
Selway	58	68	64	73	59	66	70	79	65	55	69	67	65	47	
Clearwater	57	60	66	59	63	67	74	77	76	76	75	75	69	49	
St. Joe	62	61	70	65	71	69	76	61	72	69	78	126	120	110	
Coeur d'Alene	42	48	48	49	52	59	73	72	85	94	87	95	79	71	
Kaniksu	34	37	42	37	37	40	54	56	66	79	91	89	134	143	
Pend Oreille	37	45	47	48	49	47	48	58	62	68	66	72	72		
Kootenai	44	46	49	55	66	55	66	70	68	69	66	76	76	76	
Flathead	47	70	72	83	66	80	73	69	73	81	79	76	64	102	
Blackfeet	33	34	36	40	45	53	64	54	75	56	71	60	60		
Cabinet	34	45	41	34	34	36	50	59	59	54	67	68	73	64	
Lolo	38	42	38	43	50	45	61	51	58	47	90	93	86	69	
East Selway	18	19	19	26	19	24	23	24	25	25					
Missoula	27	29	24	33	34	35	32	37	37	37					
Bitterroot	18	18	21	19	17	18	21	27	27	26	50	45	48	45	
Salmon Mtn.	17	18	16	17	19	18	29	19	26	22					
Total	601	679	692	720	722	753	853	870	926	911	956	1001	1000	816	

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Numbers of men shown are averages for the six 10-day periods of July and August, as shown by Operation's form 930 fire statistics.

Table 31. Regular firemen provided in each year of period 1921-31 for burning conditions classed as average

National-forest unit [1]	Number of firemen [2] employed in designated season										
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Nezperce	31	31	32	34	33	31	35	37	40	42	42
Selway	43	51	51	50	53	63	66	61	62	53	63
Clearwater	38	47	46	44	44	48	54	57	56	57	59
St. Joe	55	55	55	57	56	53	60	55	56	53	63
Coeur d'Alene	32	36	35	38	40	42	52	55	61	69	74
Kaniksu	33	35	38	39	40	38	52	54	50	65	73
Pend Oreille	24	33	37	40	43	42	46	45	41	51	60
Kootenai	39	42	54	53	52	57	51	61	59	59	59
Flathead	48	55	61	49	54	57	66	67	68	71	72
Blackfeet	24	24	32	27	32	40	53	48	55	49	51
Cabinet	30	28	30	31	26	32	37	43	42	41	64
Lolo [3]	69	72	78	83	86	87	98	94	96	90	75
Bitterroot	33	34	37	38	38	41	41	44	50	49	48
Total	499	542	586	583	597	631	711	721	736	749	803

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Men whose primary responsibility was detection and smokechasing. Data obtained from rangers' organization charts, made each year after allotments for current season were known. Data for seasons later than 1931 not shown because noncomparable owing to presence of large numbers of crews.

3/ Rangers' charts lost. Data obtained by applying ratio of number of firemen to total temporary force on other forests covered by this study.

Table 32. Stations occupied by firemen when burning conditions were classed as average in 1921-31 and in 1934-35

National-forest unit 1/	Number of stations occupied 2/ in each designated season													
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Nezperce	26	26	27	29	28	27	31	33	37	42	41			68	
Selway	24	30	30	30	33	41	37	39	41	48	53				
Clearwater	22	27	27	26	27	31	32	33	35	41	51			51	
St. Joe	32	33	32	33	35	38	45	50	55	52	62			92	
Coeur d'Alene	31	34	34	34	34	34	36	38	42	47	70			56	
Kaniksu	27	28	31	32	33	30	40	43	42	57	73			114	
Pend Oreille	23	31	36	34	35	34	36	38	41	51	60				
Kootenai	38	39	48	45	44	49	45	57	56	58	62			83	
Flathead	46	52	59	46	52	54	61	63	63	67	72			88	
Blackfeet	23	22	28	27	32	40	48	44	51	47	49				
Cabinet	28	26	25	21	20	20	33	39	40	40	57			51	
Lolo 3/	48	50	48	55	58	61	66	67	71	71	78			78	
Bitterroot	28	29	29	33	35	39	38	41	47	46	48			38	
Total	396	427	454	445	466	498	548	585	621	667	776			719	

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Data for 1921-30, inclusive, obtained from rangers' organization charts, made each year after allotments for current season were known. Data for 1931 and 1934 taken from records compiled in connection with present study.

3/ Rangers' charts lost. Data for 1921-30, inclusive, obtained by applying ratio of numbers of stations occupied to total regular temporary force on other forests covered by this study.

Table 33. Fireman stations at which dwellings were provided in 1921-30 and 1934-35

National-forest unit 1/	Number of stations having dwellings 2/ in designated seasons														
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Nezperce	15	15	19	20	21	21	26	33	37	42				65	
Selway	24	29	34	35	38	40	44	46	47	30					
Clearwater	5	13	15	18	20	23	22	28	31	39				46	
St. Joe	18	23	25	26	26	29	30	37	43	45				61	
Coeur d'Alene	20	21	20	23	25	29	34	30	36	44				50	
Kaniksu	14	18	19	19	20	20	24	31	34	42				100	
Pend Oreille	10	12	14	13	13	13	16	24	32	38					
Kootenai	14	17	19	21	22	23	24	45	49	58				65	
Flathead	17	17	19	19	18	19	43	51	58	66				86	
Blackfeet	6	7	8	8	7	7	9	14	17	35					
Cabinet	11	15	15	16	17	17	18	19	28	40				47	
Lolo 3/	22	26	26	32	35	36	42	48	58	59				65	
Bitterroot	12	14	13	13	15	14	14	18	22	22				21	
Total	188	227	246	263	277	291	346	424	492	560				606	

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Data for 1921-30, inclusive, obtained from improvement records of forests; those for 1934-35 taken from records compiled in connection with this study.

3/ Record of occupied stations lost. Data obtained by applying ratio of fireman dwellings to total regular temporary force on other forests covered by this study.

Table 34. Emergency guards employed in 1921-35

National-forest unit 1/	Number of men employed 2/ in designated season														
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Nezperce	0	0	0	11	15	17	13	7	21	29	62	0	0	17	
Selway	0	9	0	28	7	35	23	26	35	58	100	0	0	14	
Clearwater	16	0	0	58	30	28	12	38	33	51	20	0	0	6	
St. Joe	2	33	0	7	3	8	6	26	18	35	92	0	0	5	
Coeur d'Alene	6	13	0	0	21	53	5	17	13	23	61	0	0	2	
Kaniksu	20	12	0	1	4	18	19	6	4	7	48	0	0	30	
Pend Oreille	24	4	0	3	6	22	9	7	22	9	49	0	0		
Kootenai	14	14	0	35	5	67	0	0	25	3	69	0	0	26	
Flathead	33	2	0	0	5	7	0	0	20	68	131	0	0	16	
Blackfeet	16	6	0	0	0	4	0	0	11	0	20	0	0		
Cabinet	14	0	0	2	2	0	0	7	18	0	61	0	0	18	
Lolo	14	0	0	0	3	2	0	0	13	13	75	0	2	5	
East Selway				0	0	0	0	0	10	0					
Missoula	48	0	0	0	0	0	0	0	7	15					
Bitterroot	5	0	0	1	0	5	14	0	8	19	38	0	0	15	
Salmon Mtn.	0	0	0	0	0	1	0	0	6	8					
Total	212	93	0	146	101	267	101	134	264	338	826	0	2	154	

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Numbers shown are maxima for July-August period. Data obtained from Operation's form 930 fire statistics.

Table 35. Men in project crews available for fire duty in 1921-35

National-forest unit [1]	Number of men available [2] in designated season													
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Nezperce	101	102	55	86	62	85	129	90	56	62	101	72	18	96	
Selway	68	100	61	73	69	103	122	144	119	193	193	123	13	88	
Clearwater	79	130	108	98	109	131	127	119	136	345	662	659	79	1,048	
St. Joe	36	66	68	74	81	114	143	87	85	145	148	496	613	1,138	
Coeur d'Alene	15	40	50	50	65	108	105	107	105	116	74	230	1,261	1,128	
Kaniksu	2	33	39	51	26	165	103	85	97	172	144	149	50	105	
Pend Oreille	6	53	43	28	41	45	79	63	38	66	117	122	80		
Kootenai	0	82	83	195	122	98	141	81	89	150	76	108	37	255	
Flathead	33	77	81	88	77	144	102	112	103	185	191	133	46	126	
Blackfeet	8	55	52	73	81	109	116	99	89	162	120	113	26		
Cabinet	0	65	54	95	70	85	87	58	57	104	87	122	47	346	
Lolo	34	50	25	28	31	41	34	53	44	74	136	154	26	179	
East Selway				42	26	39	41	25	31	45					
Missoula	10	34	37	65	37	22	18	27	18	32					
Bitterroot	3	13	18	28	18	19	27	29	11	19	51	44	32	694	
Salmon Mtn.	53	32	42	29	17	29	29	28	37	51					
Total	448	932	816	1,103	932	1,337	1,403	1,207	1,115	1,921	2,100	2,525	2,328	5,203	

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Numbers are maxima for July-August period. Data obtained from Operation's form 930 fire statistics.

Table 36. Project crews available for fire duty in 1921-31

National-forest unit [1]	Number of project crews available [2] in designated season										
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Nezperce	6	6	6	13	12	14	11	14	14	14	16
Selway	14	12	13	12	10	9	9	16	20	24	35
Clearwater	6	10	15	20	21	24	19	30	21	24	28
St. Joe	4	6	7	4	8	15	13	20	26	29	35
Coeur d'Alene	7	7	9	14	10	8	12	19	18	24	23
Kaniksu	12	8	10	11	10	21	35	24	27	30	20
Pend Oreille	1	4	5	5	8	6	7	20	15	18	18
Kootenai	0	6	8	8	8	10	10	17	20	27	23
Flathead	5	8	8	11	10	17	12	34	35	35	25
Blackfeet	2	4	4	9	10	11	11	13	13	19	17
Cabinet	6	7	13	10	13	13	9	16	15	17	24
Lolo [3]	11	13	14	21	21	25	26	35	36	37	26
Bitterroot	6	6	8	8	9	14	16	12	11	18	13
Total	80	97	120	146	150	187	190	270	271	316	308

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Data obtained from rangers' organization charts, made each year after allotments for current season were known. The crews shown include those employed in such work as trail, road, and building construction or maintenance or in any other work so located that rangers considered them available for fire duties.

3/ Rangers' charts lost. Data obtained by applying ratio of number of available crews to total regular temporary force on other forests covered by this study.

Table 37. Total stations occupied for any kind of work

National-forest unit [1]	Number of stations occupied [2] in designated season										
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Nezperce	32	32	33	42	40	41	42	47	51	56	57
Selway	38	42	43	42	43	50	46	55	61	72	88
Clearwater	28	37	42	46	48	55	51	63	56	65	79
St. Joe	36	39	39	37	43	53	58	70	81	81	97
Coeur d'Alene	38	41	43	48	44	42	48	57	60	71	93
Kaniksu	39	36	41	43	43	51	75	67	69	87	93
Pend Oreille	24	35	41	39	43	40	43	58	56	69	78
Kootenai	38	45	56	53	52	59	55	74	76	85	85
Flathead	51	60	67	57	62	71	73	97	98	102	97
Blackfeet	25	26	32	36	42	51	59	57	64	66	66
Cabinet	34	33	38	31	33	33	42	55	55	57	81
Lolo	59	63	62	76	79	86	92	102	107	108	94
Bitterroot	34	35	37	41	44	53	54	53	58	64	61
Total	476	524	574	591	616	685	738	855	892	983	1,069

1/ Names indented are those of administrative units that existed for parts of the study period and were then merged with the national forests indicated.

2/ Source of data is shown in footnotes of tables 31 and 36, of which this table is a summary.

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PERIMETER OF FIRE CORRESPONDING WITH AREA ENCLOSED

The data are placed on the last pages of the report to make them most easily available for reference.

Fire damage is a consideration of the area enclosed within the fire perimeter. But it is along the perimeter that a rate of work is performed and costs of control are incurred. For many purposes, including current attacks on fires, reported in terms of area, and making reports, it is necessary to convert area to corresponding perimeter, and vice versa, to convert perimeter to corresponding area. In order to do this to a reasonable degree of accuracy, a thorough investigation of the relationship was made, based on the following data;

66 fires smaller than 50 acres selected at random from fire reports
48 fires of 50-400-acre size selected at random from fire reports
32 fires of 0.1-100-acre size measured with instruments
102 hypothetical fires of 3 shape classes drawn and measured on paper
248 fires, total

It was found, for any size class, that the probable perimeter was 1.5 times that of the circumference of a circle corresponding to the area, and that 92 percent of all the perimeters investigated were less than 2.0 times such a circumference.

For any area the smallest possible perimeter is that of a circle. From tables of circumferences for different areas, found in standard engineering handbooks, the relation of circumference to area can be plotted. Above this curve another can be plotted with ordinates twice that of the first curve. Between these two curves 92 percent of perimeter-area relationships can be expected to fall. If a third curve is plotted half way between these two, it will represent the probable perimeter for any area of fire or the average for a large number of fires.

In table 38 are shown the values that correspond to different points along each of the curves of figure 36. Since each of these curves is a parabola, it can be, and was, plotted directly from its equation. For this purpose the equations are given.

Let P = Perimeter, and A = Area
When the perimeter is a circumference,

$$P_{1.0}^2 = 4\pi A \quad , \quad P_{1.0} = \sqrt{12.56636\ A}$$

When the perimeter is 1.5 times a circumference,

$$P_{1.5}^2 = 9\pi A \quad , \quad P_{1.5} = \sqrt{28.27431\ A}$$

When the perimeter is 2.0 times a circumference,

$$P_{2.0}^2 = 16\pi A \quad , \quad P_{2.0} = \sqrt{50.26544\ A}$$

Table 38.—Perimeter of fire corresponding with area enclosed by it.

Perimeter is shown in linear units of the same kind as the square units used for area. If area is in square chains, perimeter is in chains.

Area	Minimum 1/ perimeter 1 C	Probable 2/ perimeter 1.5 C	Maximum 3/ perimeter 2 C	Area	Minimum perimeter 1 C	Probable perimeter 1.5 C	Maximum perimeter 2 C
1	3.5	5.25	7.00	210	51.4	77.10	102.80
2	5.0	7.50	10.00	220	52.5	78.75	105.00
3	6.1	9.15	12.20	230	53.7	80.55	107.40
4	7.1	10.65	14.20	240	54.8	82.20	109.60
5	8.0	12.00	16.00	250	56.0	84.00	112.00
6	8.7	13.05	17.40	260	57.1	85.65	114.20
7	9.4	14.10	18.80	270	58.3	87.45	116.60
8	10.0	15.00	20.00	280	59.4	89.10	118.80
9	10.6	15.90	21.20	290	60.4	90.60	120.80
10	11.2	16.80	22.40	300	61.5	92.25	123.00
11	11.7	17.55	23.40	320	63.4	95.10	126.80
12	12.3	18.45	24.60	340	65.4	98.10	130.80
13	12.8	19.20	25.60	360	67.2	100.80	134.40
14	13.2	19.80	26.40	380	69.1	103.65	138.20
15	13.7	20.55	27.40	400	70.9	106.35	141.80
16	14.2	21.30	28.40	425	73.1	109.65	146.20
17	14.6	21.90	29.20	450	75.2	112.80	150.40
18	15.1	22.65	30.20	475	77.2	115.80	154.40
19	15.5	23.25	31.00	500	79.3	118.95	158.60
20.0	15.9	23.85	31.80	550	83.2	124.80	166.40
22.5	16.8	25.20	33.60	600	86.8	130.20	173.60
25.0	17.7	26.55	35.40	650	90.4	135.60	180.80
27.5	18.6	27.90	37.20	700	93.7	140.55	187.40
30.0	19.4	29.10	38.80	750	97.0	145.50	194.00
32.5	20.3	30.45	40.60	800	100.2	150.30	200.40
35.0	21.0	31.50	42.00	850	103.4	155.10	206.80
37.5	21.7	32.55	43.40	900	106.3	159.45	212.60
40.0	22.4	33.60	44.80	950	109.3	163.95	218.60
42.5	23.2	34.80	46.40	1000	112.1	168.15	224.20
45.0	23.7	35.55	47.40	1050	114.8	172.20	229.60
47.5	24.5	36.75	49.00	1100	117.5	176.25	235.00
50.0	25.0	37.50	50.00	1150	120.2	180.30	240.40
52.5	25.8	38.70	51.60	1200	122.8	184.20	245.60
55.0	26.3	39.45	52.60	1250	125.4	188.10	250.80
57.5	26.8	40.20	53.60	1300	127.8	191.70	255.60
60.0	27.5	41.25	55.00	1350	130.3	195.45	260.60
65.0	28.6	42.90	57.20	1400	132.6	198.90	265.20
70.0	29.7	44.55	59.40	1450	134.9	202.35	269.80
75.0	30.7	46.05	61.40	1500	137.3	205.95	274.60
80.0	31.7	47.55	63.40	1550	139.6	209.40	279.20
85.0	32.6	48.90	65.20	1600	141.8	212.70	283.60
90.0	33.6	50.40	67.20	1650	144.0	216.00	288.00
95.0	34.6	51.90	69.20	1700	146.1	219.15	292.20
100.0	35.5	53.25	71.00	1750	148.3	222.45	296.60
110.0	37.2	55.80	74.40	1800	150.4	225.60	300.80
120.0	38.7	58.05	77.40	1850	152.5	228.75	305.00
130.0	40.4	60.60	80.80	1900	154.6	231.90	309.20
140.0	41.9	62.85	83.80	1950	156.5	234.75	313.00
150.0	43.3	64.95	86.60	2000	158.6	237.90	317.20
160.0	44.8	67.20	89.60	2050	160.5	240.75	321.00
170.0	46.2	69.30	92.40	2100	162.5	243.75	325.00
180.0	47.5	71.25	95.00	2150	164.4	246.60	328.80
190.0	48.8	73.20	97.60	2200	166.3	249.45	332.60
200.0	50.2	75.30	100.40				

1/ Perimeter is that of a circle corresponding with the area.
2/ Perimeter is 1.5 times that of a circle corresponding with the area.
3/ Perimeter is 2.0 times that of a circle corresponding with the area.

Table 38 (Continued).—Perimeter of fire corresponding with area enclosed by it.

Perimeter is shown in linear units of the same kind as the square units used for area.
If area is in square feet, perimeter is in feet.

Area	Minimum 1/ perimeter 1 C	Probable 2/ perimeter 1.5 C	Maximum 3/ perimeter 2 C	Area	Minimum perimeter 1 C	Probable perimeter 1.5 C	Maximum perimeter 2 C
2,000	159	238	318	102,000	1132	1698	2264
4,000	222	334	445	104,000	1144	1716	2288
6,000	270	405	540	106,000	1154	1731	2308
8,000	317	476	635	108,000	1165	1747	2330
10,000	355	532	710	110,000	1175	1762	2350
12,000	388	581	775	112,000	1185	1777	2370
14,000	417	626	835	114,000	1196	1794	2392
16,000	447	670	893	116,000	1206	1810	2413
18,000	475	712	950	118,000	1216	1824	2432
20,000	500	750	1000	120,000	1226	1839	2452
22,000	525	787	1050	122,000	1236	1854	2472
24,000	550	825	1100	124,000	1246	1869	2492
26,000	574	861	1148	126,000	1257	1885	2514
28,000	595	892	1190	128,000	1266	1899	2532
30,000	615	922	1230	130,000	1275	1912	2550
32,000	635	952	1270	132,000	1286	1929	2572
34,000	655	982	1310	134,000	1295	1942	2590
36,000	675	1012	1350	136,000	1305	1957	2610
38,000	692	1039	1385	138,000	1315	1972	2630
40,000	710	1065	1420	140,000	1324	1986	2648
42,000	727	1091	1455	142,000	1334	2001	2668
44,000	745	1117	1490	144,000	1343	2014	2686
46,000	762	1144	1525	146,000	1351	2026	2702
48,000	778	1168	1557	148,000	1360	2040	2720
50,000	794	1191	1588	150,000	1370	2055	2740
52,000	810	1215	1620	152,000	1379	2068	2758
54,000	825	1237	1650	154,000	1387	2081	2775
56,000	840	1260	1680	156,000	1396	2094	2792
58,000	855	1282	1710	158,000	1405	2107	2810
60,000	870	1305	1740	160,000	1413	2119	2826
62,000	885	1327	1770	162,000	1422	2134	2845
64,000	899	1348	1798	164,000	1431	2146	2862
66,000	912	1369	1825	166,000	1440	2160	2880
68,000	926	1390	1853	168,000	1449	2173	2898
70,000	940	1410	1880	170,000	1456	2184	2912
72,000	953	1429	1905	172,000	1465	2197	2930
74,000	966	1450	1933	174,000	1474	2211	2948
76,000	979	1468	1958	176,000	1481	2221	2962
78,000	992	1488	1984	178,000	1490	2235	2980
80,000	1004	1506	2008	180,000	1499	2248	2998
82,000	1016	1524	2032	182,000	1508	2262	3016
84,000	1028	1543	2057	184,000	1516	2274	3032
86,000	1040	1560	2080	186,000	1525	2287	3050
88,000	1052	1579	2105	188,000	1537	2306	3075
90,000	1064	1596	2128	190,000	1541	2311	3082
92,000	1075	1612	2150	192,000	1550	2325	3100
94,000	1087	1631	2175	194,000	1559	2338	3118
96,000	1099	1648	2198	196,000	1566	2349	3132
98,000	1110	1665	2220	198,000	1575	2362	3150
100,000	1121	1681	2242	200,000	1581	2371	3162

1/ Perimeter is that of a circle corresponding with the area.
2/ Perimeter is 1.5 times that of a circle corresponding with the area.
3/ Perimeter is 2.0 times that of a circle corresponding with the area.

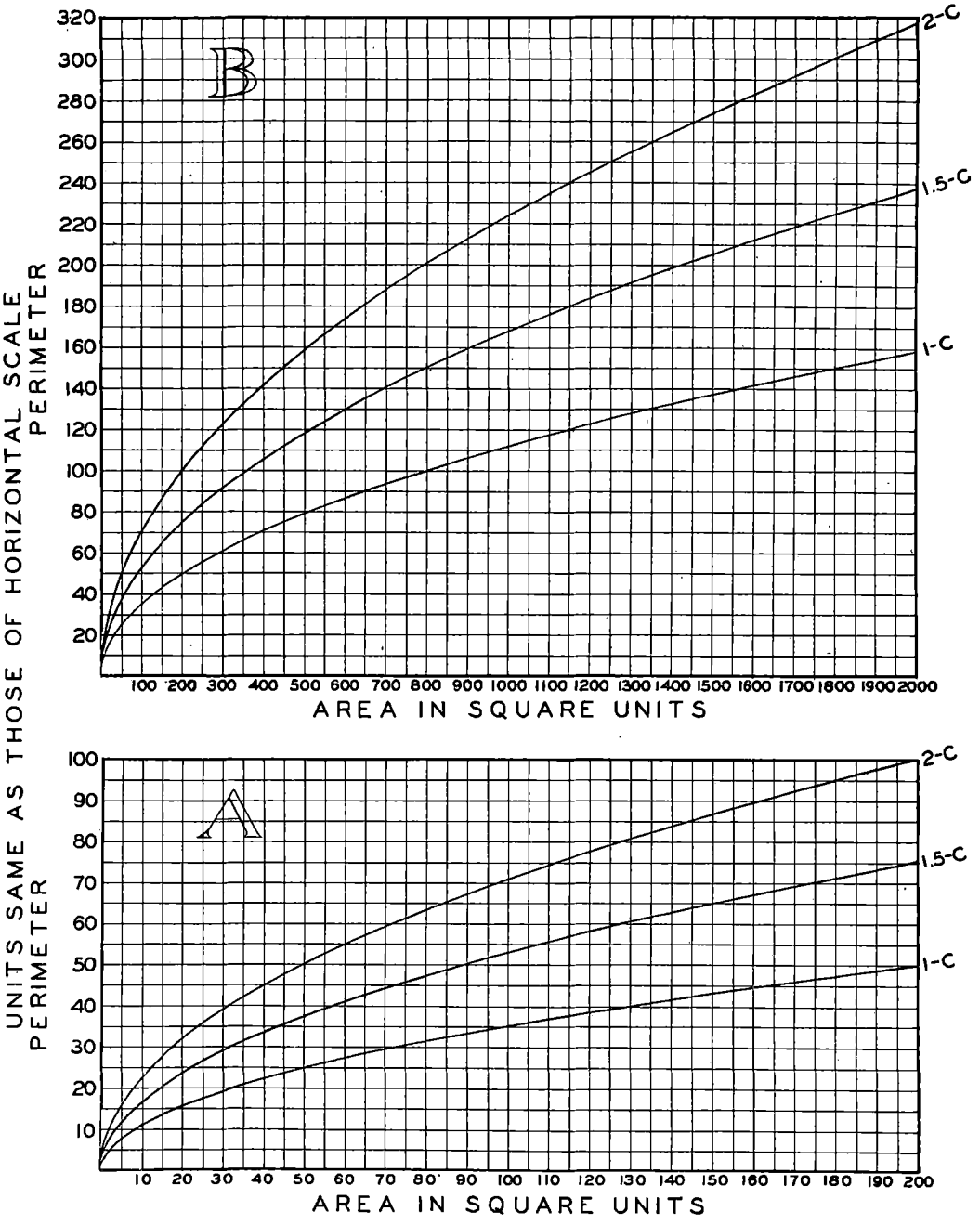


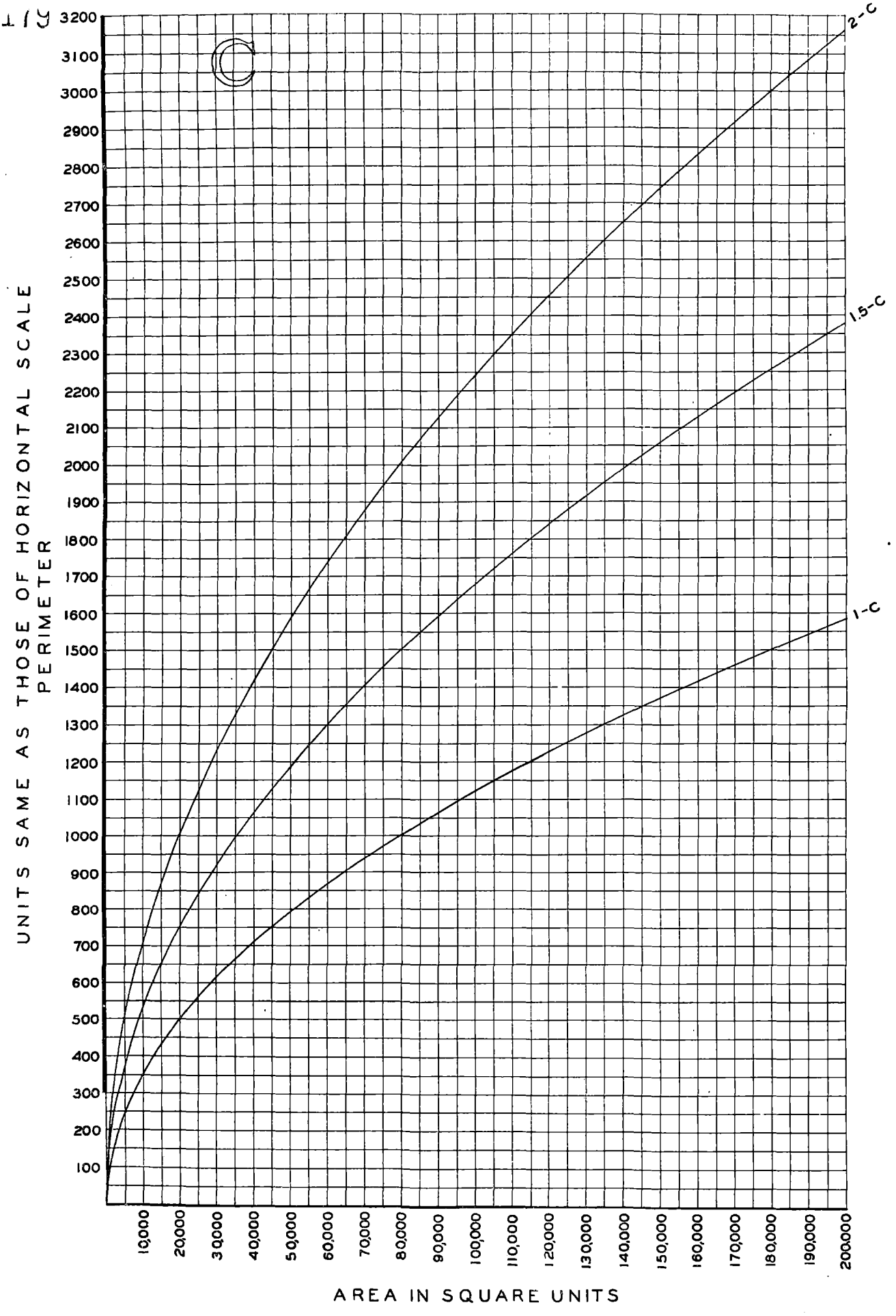
Figure 36.--Perimeter of fire corresponding with area enclosed by it.

1.0-C The "1-C" curve shows the circumference of a circle. This is the least possible perimeter.

1.5-C The "1.5-C" curve shows the probable or average perimeter to be expected. It is 1.5 times the circumference of a circle.

2.0-C Very irregular perimeters will fall between the "1.5-C" and "2-C" curves. Not more than 8 percent of all cases will lie above the "2-C" curve. It is 2.0 times the circumference of a circle.

The perimeter shown by the vertical scale is expressed in linear units of the same kind as the square units of area shown by the horizontal scale. Thus, for areas in square feet the perimeter in feet is shown; for square chains, it is shown in chains. When areas are expressed in acres, move the decimal point one place to the right to obtain square chains; the corresponding perimeter in chains is shown.


UNITS SAME AS THOSE OF HORIZONTAL SCALE
PERIMETER
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
2-C
1.5-C
1-C
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000
150,000
160,000
170,000
180,000
190,000
200,000
AREA IN SQUARE UNITS